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# ENGINEERING DESIGN HANDBOOK

## ROCKET AND MISSILE CONTAINER ENGINEERING GUIDE



US ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND JANUARY 1982

DEPARTMENT OF THE ARMY
HEADQUARTERS US ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND
5001 Eisenhower Avenue, Alexandria, VA 22333

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ENGINEERING DESIGN HANDBOOK

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# PREFACE

Each of us has experienced the disappointment, frustration, or hostility of opening a package only to discover the contents is unserviceable because of faulty packaging. We have the luxury of time to exchange the damaged item for a serviceable one. The soldier in the field is not afforded this luxury—the item he unpacks must be serviceable if the unit's mission is to be accomplished. Accordingly, this handbook is a guide for the design of adequate—not "gold-plated"—containers for missiles and rockets. The data are based on years of experience dating back to the CORPORAL rocket by the designers of missiles and rockets. In fact, this handbook is a revision, for publication in the Engineering Design Handbook series, of an in-house guide prepared by the US Army Missile Command. Engineers are encouraged to make maximum use of this container engineering guide to ensure adequate packaging for missiles and rockets.

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# CHAPTER 1
# PRINCIPLES OF MILITARY CONTAINER DESIGN

*The degree of protection provided by a container is dependent upon its components and their performance when functioning collectively. The challenge to the designer lies in the selection of the type and amount of materials, which when assembled according to scientific principles, will perform both effectively and efficiently within the pertinent operating environment. The contents of this chapter are oriented toward the provision of essential definitions, instructions, and reference data useful in establishing the basic design requirements for the working mechanical components of a container.*

## 1-0 LIST OF SYMBOLS

$A$ = area under curve of shock pulse, $ft^2$
$a$ = maximum allowable acceleration object can safely withstand, $ft/s^2$
$d$ = minimum deflection, in.
= distance of travel, in.
$d_b$ = available displacement at hard bottoming for tangentially elastic cushioning, in.
$d_m$ = minimum displacement for tangentially elastic cushioning, in.
$f$ = forced frequency, Hz
$f_n$ = approximate natural frequency, Hz
$F$ = force of impact, lb
$g$ = acceleration due to gravity, $ft/s^2$
$G$ = acceleration, g-units
$G_m$ = fragility factor, g-units
= $G$-factor of container as designed, g-units
$h$ = drop height, in.
$k$ = spring constant, lb/in.
$m$ = mass of container, $lb{\cdot}s^2/ft$ (slug)
$r$ = $f/f_n$, dimensionless
$R$ = rate of travel, length/time
$t$ = time interval required to dissipate force, s
= shock-rise time, ms
= time, s
$t_m$ = deceleration time, ms
= maximum shock-rise time, ms
$V$ = velocity of container at moment of impact, ft/s
$W$ = weight, lb

## 1-1 FRAGILITY

The level of protection required of a container is dictated by the characteristics of the object to be protected and the environment in which the container must operate. Of prime import to container design is the characteristic of fragility. This relates to the ability of an object to withstand the effects of externally applied forces. The term fragility pertains to the sensitivity of the object to damage and alludes to its degree of inherent elasticity.

## 1-2 THE $G_m$-FACTOR

The basis for the measurement of fragility is the $G_m$-factor; a dimensionless ratio of the maximum acceleration that an object can safely withstand to the acceleration due to gravity:

$$G_m = a/g, \text{ g-units} \tag{1-1}$$

where

$a$ = maximum allowable acceleration an object can safely withstand, $ft/s^2$
$g$ = acceleration due to gravity, 32 $ft/s^2$.

At present, there are no suitable analytical techniques for determining $G_m$. Since $G_m$ is a nebulous number, it appears that duplication of the impact environment is probably the best way to determine a value for $G_m$.

Prior to conducting costly, time-consuming, destructive tests, it may be more practical to apply the "educated guess" technique. Table 1-1 may be used as a guide to assist in establishing a fragility level where the $G_m$-factor of the item is not known. An item with a low $G_m$-factor is considered fragile; one with a high $G_m$-factor is considered rugged. The $G_m$-factor often is provided by the manufacturer of the item to be protected. When this value is not known, the table may serve as an approximate guide; however, it should never be considered a substitute for test information.

Essentially, the $G_m$-factor is a measure of item elasticity, i.e., its inherent capacity to retain or recover its shape upon or after the application of a distorting force. If the distorting force is in excess of the $G_m$-factor of the item, the elastic limit of the item may be exceeded and result in permanent distortion and possible failure. The function of the container is to attenuate—to a level equal to or less than the critical $G_m$-factor of the item to be protected—the forces transmitted to its contents. The magnitude of these forces and their duration constitute the hazard, and it is these forces with which the designer is most concerned.

**TABLE 1-1**
**APPROXIMATE FRAGILITY OF TYPICAL PACKAGED ARTICLES**

| | |
|---|---|
| Extremely Fragile | |
| Missile guidance systems, precision instruments | $15 \leq G_m < 25$ |
| Very Delicate | |
| Mechanically shock-mounted instruments and electronic equipment | $25 \leq G_m < 40$ |
| Delicate | |
| Aircraft accessories and other electrically operated equipment | $40 \leq G_m < 60$ |
| Moderately Delicate | |
| Television receivers and components | $60 \leq G_m < 85$ |
| Moderately Rugged | |
| Appliances, etc. | $85 \leq G_m < 115$ |
| Rugged | |
| Machinery, weldments, etc. | $G_m \geq 115$ |

## 1-3 IMPACT SHOCK

The most critical of externally applied forces imposed upon the container is that of shock. Shock occurs when the container is subjected to a suddenly applied force. The most severe shock is generally that which occurs when the container is dropped upon a rigid surface. This may be expected when the container is dropped freely, for example, from a truck onto a loading platform.

The principal methods of investigating shock phenomena in use today are (1) analytical calculations, and (2) physical testing. Analytical calculations are used primarily as a starting point. Beyond this point, most problems involve calculations so complex that it is impractical to pursue this approach—after extended calculations, the results are at best only approximate. The majority of impact-shock problems can be solved most economically by physical testing; however, in order to obtain a suitable test specimen or prototype, the design procedure must begin with analytical calculations.

Impact shock results when a container is dropped through a vertical distance onto a relatively nonresilient surface. In practice it is impossible to predict impact conditions because the container will not impinge on a surface in exactly the same manner each time it is dropped; consequently, any assessment of shock experienced by the container is at best approximate.

To simulate and subject the test specimen to the most critical condition of impact, the testing of military containers normally is performed with the test specimen impinging upon a concrete slab having significant shock-mitigating characteristics. This qualification criterion establishes a design parameter affecting the analytical calculations.

The maximum impact force imposed upon the free-falling container is dependent upon the deflection experienced by either or both impacting bodies. Since the impacting surface has been established as having insignificant shock-mitigating characteristics, it can be assumed that any deflection will be experienced only by the container. The impact force (shock) imposed upon the container will depend upon the amount of deflection necessary to bring the container to rest; the smaller the deflection, the larger will be the impact force.

To determine the magnitude of an impact force, the kinetic energy of the container at the instant immediately preceding impact must be calculated. This kinetic energy (inch·pound units) is equal to the potential energy of the container before it is dropped, which in turn is equal to the weight of the container (pounds) multiplied by the vertical distance (inches) through which it is dropped. To bring the container to rest after impact, the container must absorb all of the kinetic energy $KE$ developed by the fall. (Note: Within the scope of this handbook, it is assumed that the concrete impact surface functions as a rigid, nonresilient barrier and as such absorbs no energy.) The function of the container is to absorb this energy by distortion and/or recoverable deflection. Crushing of the container body or flexing of a resilient suspension system provides physical displacement of a mass through a distance in a specific time. The physical relationship which defines this contention is expressed as:

$$Ft = mV, \text{ lb}\cdot\text{s} \tag{1-2}$$

where

$F$ = force of impact, lb
$t$ = time interval required to dissipate the force $F$, s
$m$ = mass of the container, lb·s²/ft (slug)
$V$ = velocity of the container at moment of impact, ft/s.

The product $mV$, the momentum of the container, is independent of the nature of the impact surface. It is apparent from Eq. 1-2 that the product $Ft$ must be the same whether the impact surface is hard or soft; and the smaller the $t$, the greater will be $F$.

(Note: When calculating the shock imposed upon a packaged item—using either an elastomeric, me-

chanical, or bulk cushioning system—the weight of the container does *not* enter into any of the calculations provided two assumptions are made:

a. Container impinges on a nonresilient surface.

b. Container is considered to be a rigid body.

Only the weight of the item and the spring constant of the suspension system influence the shock transmitted to the item. For this reason, a suspension system can be designed to provide protection to an item *before* a container body or shell is designed.)

Accordingly, when an object is stopped in a very short time, such as when it strikes a hard surface, the force developed is very large. Consequently, any reference to the magnitude of impact in $G$'s ($G = F/W$) must necessarily include a time factor; otherwise, this ratio $G$ or indication of applied force cannot be correlated to any impact damage criterion ($G_m$-factor). Shock therefore can be described as the disturbance produced by a suddenly applied force in the form of a complex pulse that can be described completely only by a Fourier analysis. In container design, it will suffice to describe shock by its amplitude in $G$'s and its duration in milliseconds.

## 1-4 SHOCK PULSE

The result of an impact is a shock pulse comprised of a combination of superimposed responses in the form of a complex wave. Since it is difficult to describe the shock wave in detail, the pulse is characterized by its peak amplitude in $G$-units (acceleration) and its time duration in milliseconds.

Impact on a hard surface produces shock pulses of a large amplitude but brief duration; impact on soft surfaces produces low-amplitude shock pulses of long duration (see Fig. 1-1). The area $A_t$ under the curve of a shock pulse is the energy of impact which is imposed upon the container. If the amplitude of the shock pulse in $G$'s produces a shock in excess of the critical fragility factor $G_m$, the impact results in failure. If the total energy is distributed over a greater time base, the container will be subjected to a shock falling within its ability to absorb. This is illustrated by Fig. 1-2.

## 1-5 PULSE DURATION

The time base of the shock pulse wave is the pulse duration. Fig. 1-3 graphically depicts the reaction of a container to impact. The impact force, generated by the free fall, builds up from a value of zero at the instant of impact to a maximum value upon final arrest. The time consumed by deceleration of the container is the shock-rise time and represents the duration of deflection experienced as the result of impact.

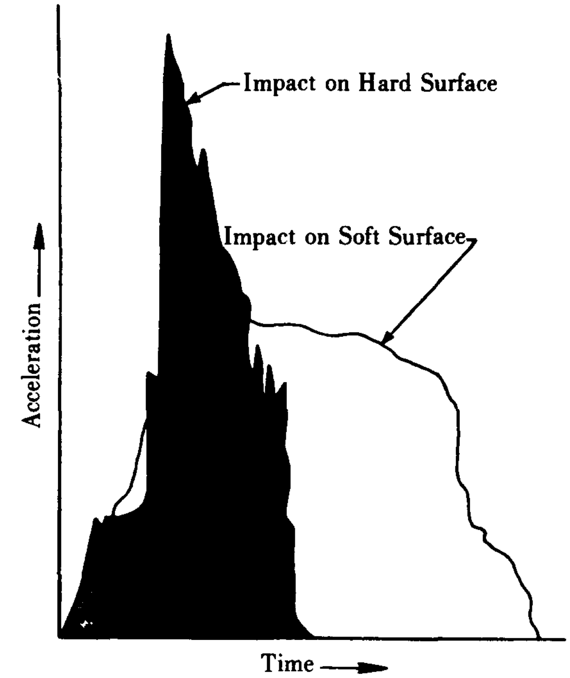


**Figure 1-1. Impact Shock Pulse**

The balance of the pulse duration is referred to as the shock-decay time and reflects upon the resiliency of the container (or suspension system) and its ability to recover.

The shock-rise time is dependent upon the yielding mass and is a function of its compressibility and elasticity. Other factors affecting shock-rise time include the resiliency of the impact surface and the extent of contact area which may be a flat or curved surface, an edge, or a point. Data relating to shock-rise time have been determined for a variety of conditions by careful instrumentation and are included in Table 1-2 to assist in the analytical design process. The importance of the shock-rise time and the ability of the designer to manipulate its value cannot be over emphasized since this constitutes the means by which shock loads are mitigated and is the basis of container technology. Subsequent chapters will present data and describe techniques to permit the selection of a material and/or design which will provide the shock-rise time necessary to mitigate the imposed shock $G$ to within the fragility level $G_m$ of the container and its contents.

## 1-6 G's DEVELOPED BY FREE-FALL IMPACT

Shock damage is caused by acceleration forces developed during impact. These forces can be measured by accelerometers and associated instrumenta-

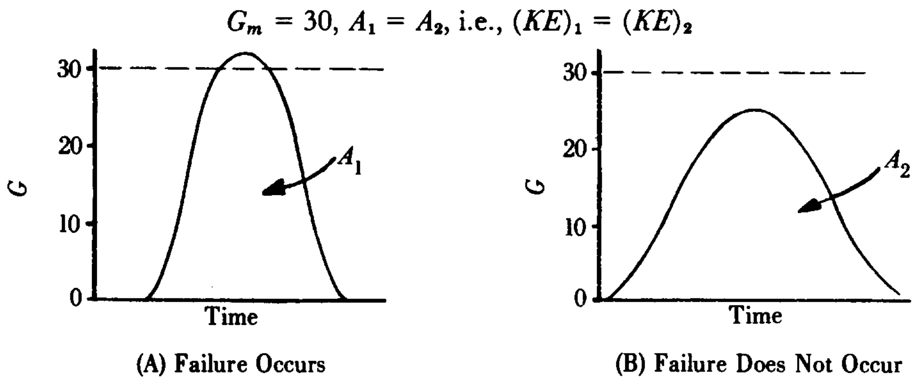


**Figure 1-2. Shock Pulse and the Critical Fragility Level**

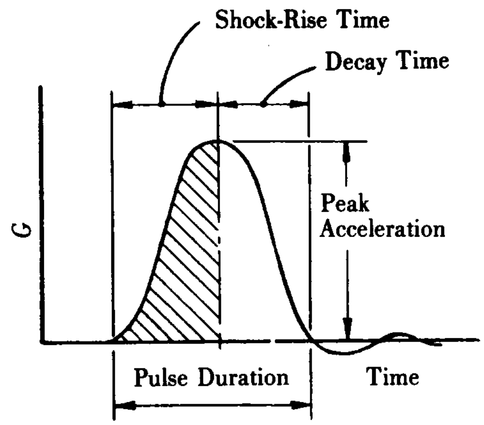


**Figure 1-3. Shock Rise and Decay**

**TABLE 1-2**
**TYPICAL VALUES FOR SHOCK-RISE TIME**

| Condition | Flat Face Contact, ms | Point Contact, ms |
|---|---|---|
| Rigid Steel against Concrete | 1 | 2 |
| Rigid Steel against Wood or Mastic | 2-3 | 5-6 |
| Steel or Aluminum against Compact Earth | 2-4 | 6-8 |
| Steel or Aluminium against Sand | 5-6 | 15 |
| Product Case against Mud | 15 | 20 |
| Product Case against 1-in. Felt | 20 | 30 |

tion; however, this is a costly procedure and is dependent upon the availability of a test specimen. For the analytical computations pertinent to the design of a prototype, useful values for maximum acceleration can be computed from the shock-rise time and drop height by Eq. 1-3.

$$G = \frac{72}{t}\sqrt{h}, \quad \text{g-units} \tag{1-3}$$

where

$G$ = acceleration, g-units
$t$ = shock-rise time, ms
$h$ = drop height, in.

Table 1-3 tabulates the magnitude of developed $G$'s for various free-fall drop conditions and permits the designer to estimate the shock imposed upon the container and/or its contents.

## 1-7 MINIMUM SHOCK-RISE TIME

To develop a practical working tool, Eq. 1-3 can be modified to reflect the shock-rise time necessary to result in a specific force falling within the $G_m$ parameter:

$$t_m = \frac{72}{G_m}\sqrt{h}, \quad \text{ms} \tag{1-4}$$

where

$t_m$ = maximum shock-rise time, ms
$G_m$ = fragility level of the container contents, g-units
$h$ = drop height, in.

The data in Table 1-3 may then be used to establish the minimum shock-rise time necessary to assure effective performance. In practice, this is accomplished by varying the resiliency of the cushioning or suspension system to provide increasingly longer pulse duration.

TABLE 1-3
$G$-MAXIMUM ACCELERATION EXPERIENCED BY A FREE-FALLING OBJECT

| Drop Height | Shock-Rise Time, ms | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $h$, in. | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 11 | 12 | 14 | 15 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| 6 | 176 | 88 | 55 | 44 | 35 | 29 | 22 | 18 | 16 | 15 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 7 | 6 | 6 |
| 12 | 252 | 126 | 84 | 62 | 50 | 42 | 31 | 25 | 23 | 21 | 18 | 17 | 16 | 14 | 12 | 11 | 10 | 10 | 9 | 8 |
| 18 | 305 | 152 | 101 | 76 | 61 | 51 | 38 | 30 | 28 | 25 | 22 | 20 | 19 | 17 | 15 | 14 | 13 | 12 | 11 | 10 |
| 20 | 322 | 161 | 107 | 80 | 64 | 53 | 40 | 32 | 29 | 26 | 23 | 21 | 20 | 17 | 16 | 14 | 13 | 12 | 11 | 10 |
| 24 | 352 | 176 | 117 | 88 | 70 | 58 | 44 | 35 | 32 | 29 | 25 | 23 | 22 | 19 | 17 | 16 | 14 | 13 | 12 | 11 |
| 30 | 394 | 197 | 131 | 98 | 78 | 65 | 49 | 39 | 35 | 32 | 28 | 26 | 24 | 21 | 19 | 17 | 16 | 15 | 14 | 13 |
| 36 | 432 | 216 | 144 | 108 | 86 | 72 | 54 | 43 | 39 | 36 | 30 | 28 | 27 | 24 | 21 | 19 | 18 | 16 | 15 | 14 |
| 40 | 455 | 227 | 151 | 113 | 91 | 75 | 56 | 45 | 41 | 38 | 32 | 30 | 28 | 25 | 22 | 20 | 19 | 17 | 16 | 15 |
| 42 | 466 | 233 | 155 | 116 | 93 | 77 | 58 | 46 | 42 | 39 | 33 | 31 | 29 | 25 | 23 | 21 | 19 | 18 | 16 | 15 |
| 48 | 498 | 249 | 166 | 124 | 99 | 83 | 62 | 49 | 45 | 41 | 35 | 33 | 31 | 27 | 25 | 22 | 20 | 19 | 17 | 16 |
| 60 | 557 | 278 | 185 | 139 | 111 | 93 | 69 | 55 | 50 | 46 | 39 | 37 | 34 | 31 | 27 | 25 | 23 | 21 | 19 | 18 |

## 1-8 DEFLECTION OR DISPLACEMENT

The underlying principle behind all protective packaging is that every object in a free-fall possesses kinetic energy which it must dissipate by decelerating through a given distance and time interval. The function of the parachute and the prizefighter's technique of "rolling with the punch" are examples of this principle.

The rate of deceleration is determined by the maximum number of $g$'s $G_m$ the item can withstand. An attempt to stop an object within too short a distance runs the risk of exceeding the maximum $G_m$, resulting in damage to the object.

The rate of deceleration of the impacting object becomes a function of the resistance of the object to crushing or, as is found in practice, the density of the protective cushion or elasticity $K$ of the suspension system. The response of the cushion or suspension is dictated by its density or spring constant which in turn is determined by the supported weight at any particular moment during deceleration. To further complicate the analytical calculations, it has been found that the response of various materials used as cushions or springs varies with the applied load; this relationship may be linear, nonlinear, or a combination of both. Within the scope of this handbook, the data that follow are adequate; derivations and more detailed presentations are available in the literature.

Consequently, it will suffice to state that the density or elasticity of the suspension material and its ability to provide the deflection required determine the amount of shock experienced by the object subjected to impact. These constitute the tools available to the designer; by varying the material and its configuration, adequate deflection or displacement can be provided to control the rate of deceleration to within the safe limits of fragility.

## 1-9 LINEAR SUSPENSION SYSTEMS

In the isolation of shock, large deflections are encountered which result in a nonlinear response of the suspension system. It is often, particularly in the environment peculiar to Army materiel, impossible to predict the maximum shock which will be encountered; consequently, large deflections must be anticipated. If the suspension does not provide for sufficient deflection and gradual increase in stiffness, bottoming may occur with consequent transmission of excessive forces. This consideration makes the use of a linear isolator undesirable. It is often preferable to employ a nonlinear isolator having anomalous force-deflection characteristics. Such an isolator may be considered linear for small deflections; additional factors must be considered, however, if the applied shock causes deflections well into the nonlinear range. The analysis of nonlinear isolators involves complex equations which may, for the sake of expediency, be circumvented. To satisfy the intent of this handbook, it will suffice merely to be aware of the nonlinearity of conventional cushioning media and

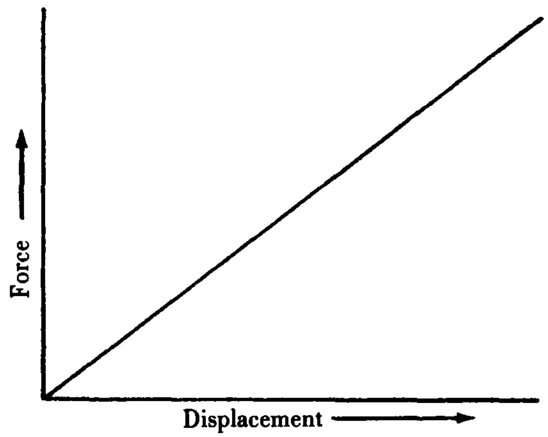


**Figure 1-4. Force-Displacement Curve For Linear Suspension Systems**

the resulting deflections which dictate the spatial requirements of the container body.

For a linear system, where the displacement is proportional to the applied load, as illustrated by Fig. 1-4, the equation

$$d = \frac{2h}{G_m - 2} \tag{1-5}$$

indicates the relationship among drop height $h$, fragility factor $G_m$, and minimum deflection $d$. Deflection $d$ is numerically equal to the distance required to decelerate the contained object dropped from a height $h$ such that the $G$'s experienced by the container will be mitigated to a level not exceeding the established fragility level $G_m$ of the protected contents. Note that $G_m$ and $d$ are inversely proportional; as the fragility factor $G_m$ is lowered, larger deflections must be provided. Table 1-4 tabulates the required $d$ for a given $h$ and $G_m$.

In summation, the distance through which an impacting object moves, prior to coming to rest, is dictated by the phenomenon of energy dissipation. This is reflected in the relationship between the peak acceleration $G$ experienced by the impacting container and the length of time (shock pulse) during which the acceleration lasts. The pulse is a function of distance and--to maintain a specific level of maximum acceleration $G_m$ experienced by the contained object—the minimum distance the contained object must travel (deflection) in being brought to rest is fixed and is theoretically independent of the suspension system or cushion provided. This deflection $d$ determines the minimum sway space which must be provided within the container and, as such, dictates the spatial dimensions of the container cavity. A linear suspension is rarely encountered in practice; however, because of its simplicity, it is usually used to determine minimum spatial requirements. A steel spring is an example of a linear-type suspension where the spring rate ($k$ in pounds per inch) is constant throughout the range of its use. This simplified analysis—which ignores damping and friction—is entirely adequate for many purposes, particularly those involving small deflections.

**TABLE 1-4**
**LINEAR SYSTEM—DEFLECTION SELECTOR CHART $d = 2h/(G_m - 2)$**

| | Drop Height $h$, in. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $G_m$ | 6 | 12 | 18 | 20 | 24 | 30 | 36 | 40 | 42 | 48 | 60 |
| 10 | 1.5 | 3.0 | 4.5 | 5 | 6 | 7.5 | 9 | 10 | 10.5 | 12.0 | 15 |
| 15 | 0.92 | 1.85 | 2.79 | 3.00 | 3.7 | 4.6 | 5.5 | 6.2 | 6.5 | 7.4 | 9.2 |
| 20 | 0.67 | 1.33 | 2.0 | 2.22 | 2.7 | 3.3 | 4.0 | 4.4 | 4.7 | 5.4 | 6.6 |
| 30 | 0.43 | 0.86 | 1.28 | 1.43 | 1.7 | 2.1 | 3.6 | 2.9 | 3.0 | 3.4 | 4.2 |
| 40 | 0.32 | 0.63 | 0.95 | 1.05 | 1.3 | 1.6 | 1.9 | 2.1 | 2.2 | 2.6 | 3.2 |
| 50 | 0.25 | 0.50 | 0.75 | 0.83 | 1.0 | 1.3 | 1.5 | 1.7 | 1.8 | 2.0 | 2.6 |
| 60 | 0.21 | 0.42 | 0.62 | 0.69 | 0.84 | 1.0 | 1.2 | 1.3 | 1.5 | 1.68 | 2.0 |
| 75 | 0.17 | 0.34 | 0.49 | 0.55 | 0.68 | 0.82 | 0.98 | 1.1 | 1.2 | 1.36 | 1.64 |
| 100 | 0.12 | 0.24 | 0.37 | 0.41 | 0.48 | 0.61 | 0.74 | 0.82 | 0.86 | 0.96 | 1.22 |
| 125 | 0.096 | 0.19 | 0.29 | 0.33 | 0.38 | 0.49 | 0.58 | 0.66 | 0.68 | 0.76 | 0.98 |

## 1-10 NONLINEAR SUSPENSION SYSTEMS

Many of the nonlinear (anomalous) cushions (see Fig. 1-5) have force-displacement curves resembling the trigonometric tangent function which cannot be expressed by simple mathematical equations. The figure shows how the stiffness of the suspension (i.e., the shape of the curve) increases as the displacement approaches the maximum available ($d_b$) at hard bottoming. The minimum amount of displacement required for nonlinear (tangentially elastic) cushioning may be expressed mathematically:

$$d_m = \frac{3.9h}{G_m}, \text{ in.} \quad (1\text{-}6)$$

where

$d_m$ = minimum displacement, in.
$h$ = drop height, in.
$G_m$ = fragility factor, g-units.

It is interesting to compare the displacements for linear and nonlinear suspensions and note that the spatial requirements are greater for nonlinear suspensions. Table 1-5 tabulates $d_m$ given $h$ and $G_m$.

## 1-11 RATE OF TRAVEL

To attain a required level of protection ($G_m$-factor), it has been shown that the item to be protected must decelerate through a specific distance $d$ to dissipate the energy of impact generated as the result of a free fall from a particular height. Travel through any distance entails time, and the ratio of this distance and time establishes the rate of travel $R$ of the object during deceleration:

$$R = \frac{d}{t}, \text{ L/T} \quad (1\text{-}7)$$

or

$$d = Rt$$

where

$d$ = distance, length units (L)
$t$ = time, time units (T).

It has been shown previously (Eq. 1-3) that the desired deceleration at impact as determined by the fragility level of the object to be protected is inversely

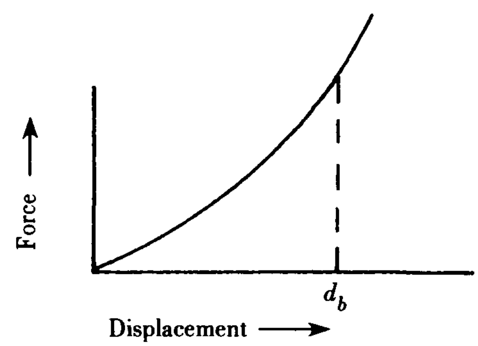


**Figure 1-5. Force-Displacement Curve For Nonlinear Suspension Systems**

**TABLE 1-5**
**NONLINEAR SYSTEMS—DEFLECTION SELECTOR CHART $d_m = 3.9h/G_m$**

| | Drop Height $h$, in. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $G_m$ | 6 | 12 | 18 | 20 | 24 | 30 | 36 | 40 | 42 | 48 | 60 |
| 10 | 2.34 | 4.68 | 7.02 | 7.80 | 9.36 | 11.7 | 14.04 | 15.60 | 16.38 | 18.72 | 23.40 |
| 15 | 1.56 | 3.12 | 4.68 | 5.20 | 6.24 | 7.80 | 9.36 | 10.4 | 10.92 | 12.48 | 15.60 |
| 20 | 1.17 | 2.34 | 3.51 | 3.90 | 4.68 | 5.85 | 7.02 | 7.80 | 8.19 | 9.36 | 11.70 |
| 30 | 0.78 | 1.56 | 2.34 | 2.60 | 3.12 | 3.90 | 4.68 | 5.20 | 5.46 | 6.24 | 7.80 |
| 40 | 0.58 | 1.17 | 1.75 | 1.95 | 2.34 | 2.93 | 3.51 | 3.90 | 4.10 | 4.68 | 5.85 |
| 50 | 0.47 | 0.94 | 1.40 | 1.56 | 1.87 | 2.34 | 2.81 | 3.12 | 3.28 | 3.74 | 4.68 |
| 60 | 0.39 | 0.78 | 1.17 | 1.30 | 1.56 | 1.95 | 2.34 | 2.60 | 2.73 | 3.12 | 3.90 |
| 75 | 0.31 | 0.62 | 0.94 | 1.04 | 1.25 | 1.56 | 1.87 | 2.08 | 2.18 | 2.50 | 3.12 |
| 100 | 0.23 | 0.47 | 0.70 | 0.78 | 0.94 | 1.17 | 1.40 | 1.56 | 1.64 | 1.87 | 2.34 |
| 125 | 0.19 | 0.37 | 0.56 | 0.62 | 0.75 | 0.94 | 1.12 | 1.25 | 1.31 | 1.50 | 1.87 |

proportional to the pulse duration $t$ of Eq. 1-7 (time to decelerate). Thus Eq. 1-3 may be rewritten as

$$G_m = \frac{72}{t_m}\sqrt{h}, \text{ g-units} \quad (1\text{-}8)$$

where

$t_m$ = deceleration time, ms.

Relating Eqs. 1-7 and 1-8 and substituting for $t_m$ its equivalent $d/R$, we have

$$G_m = R\left(\frac{72}{d}\sqrt{h}\right) \quad (1\text{-}9)$$

where the distance unit for $R$ and $d$ must be the same.

Considering the value $72\sqrt{h}/d$ a constant, we conclude that $R$, the rate of travel during deceleration, is directly proportional to the $G_m$ factor. To reduce the value of $G_m$, we must reduce the numerical value of $R$—i.e., prolong the time of deceleration which in effect is the pulse duration. The state of the art makes available to packaging technology various means by which the designer can provide for the required displacement $d$ and simultaneously control the rate of travel $R$ during deceleration through this distance $d$. The value of the controlled rate of travel $R$ during deceleration as determined by the required pulse duration $t$ establishes the magnitude of the shock $G_m$ experienced by the object to be protected. The various means available to the design engineer include elastomeric, mechanical, and bulk cushioning suspension systems which, because of their contribution and performance, are discussed in depth in subsequent chapters of this handbook.

## 1-12 IMPOSED VIBRATION

A condition peculiar to materiel in transit is that of vibration generated by the carrier vehicle. The carrier, functioning as a fluctuating force, imparts to the container a forced vibration; the container (assumed to be restrained) is forced to vibrate at the same frequency as that of the carrier. Should these vibrations coincide with the natural frequency of the suspended contents, the associated forces may become great enough to cause fracture or damage to the contained item. Carrier vehicles in transit are subjected to conditions resulting in vibrations peculiar to the environment in which they operate. Many studies have been conducted to determine the most common forcing frequencies that will be encountered by different carriers and, although exceptions are found, the following summary is generally applicable:

a. Railroad: 2 to 7 Hz
b. Truck: 20 to 200 Hz
c. Aircraft: 20 Hz and 60 Hz
d. Ships: 11 to 100 Hz.

The mode of transportation and the applicable frequencies tabulated provide the required data relating to imposed vibrations.

## 1-13 NATURAL FREQUENCY

Determination of the natural frequency of a container system is of the greatest importance to permit comparison with the forced vibration introduced by the carrier. This comparison of frequency is essential if a damaging resonant condition is to be avoided. The natural frequency of a suspended system is that frequency at which the system will vibrate if displaced and allowed to vibrate freely. Any system comprised of a body suspended on cushioning has a natural frequency at which it will vibrate with greater amplitude than at a frequency just above or below it. To determine a rough approximation of the vertical natural frequency of a container system, apply Eq. 1-10.

$$f_n = \frac{2G_m}{\sqrt{h}}, \text{ Hz} \quad (1\text{-}10)$$

where

$G_m$ = G-factor of the container as designed, g-units
$h$ = drop height, in.
$f_n$ = approximate natural frequency, Hz.

## 1-14 RESONANCE

Bodies subjected to periodic impulses imparted by outside agents are said to execute forced vibrations. When conditions are adjusted so that the frequency of forced vibrations is the same as the natural frequency of the body upon which they are impressed, the free vibrations reinforce the received ones; an effect which is known as resonance. When the impressed vibration has a frequency different from that of the free vibration of the body, the received impulses will not affect the free vibrations appreciably. There are instances where resonance may build up free vibrations of such amplitude as to produce dangerous results. The amplitude of vibration depends upon the magnitude of the forced vibration and the ratio of its frequency to the natural frequency of the object or system being vibrated. When this frequency ratio $r$ (defined by Eq. 1-11) becomes equal to unity,

the amplitude of the vibration may build up to a dangerous value.

$$r = \frac{f}{f_n}, \text{ dimensionless} \qquad (1\text{-}11)$$

where

$f$ = forced frequency, Hz
$f_n$ = natural frequency, Hz.

When $r = 1$, there is said to be resonance between the frequency of the disturbing force and the natural frequency of the system. In all practical problems, the maximum amplitude obtainable would be limited by failure of the system or limitations of space. Theoretically, for the effective isolation of vibratory forces, the ratio between the disturbing frequency $f$ and the natural frequency $f_n$ of the system must always be greater than $\sqrt{2}$; and, as this ratio assumes values greater than $\sqrt{2}$, the system becomes progressively more efficient. Conversely, as the ratio $f/f_n$ becomes less than $\sqrt{2}$, magnification of the vibratory forces will occur, and this condition must be avoided. As the ratio of $f/f_n$ approaches the value of unity, the magnitudes of the vibratory forces are increased until at unity, where resonance occurs, they become infinite. Mathematically this relationship is expressed by Eq. 1-12 which is known as the transmissibility equation

$$\text{Transmissibility} = \frac{1}{\left(\frac{f}{f_n}\right)^2 - 1}, \text{ dimensionless} \qquad (1\text{-}12)$$

where

$f$ = disturbing frequency, Hz
$f_n$ = natural frequency of mounted assembly, Hz.

The purpose of most vibration investigations is to avoid the occurrence of resonance.

The preceding data have been presented as orientation in order to acquaint the reader with the principles of container design. These and other aspects of this technology are discussed in depth in subsequent chapters.

To minimize the design effort, the service requirements with respect to shock and vibration have been established for those conveyances most common to the transport of Army materiel. When permissible, it is desirable to investigate all aspects of an environment and the hazards it presents; however, should time be of the essence, it is suggested that the following critical conditions be investigated first:

a. *Rail Shipments.* Failures are caused most often by high impact shocks; a single transient shock wave is imparted to the equipment, and failure is instantaneous. Vibration becomes a secondary consideration.

b. *Truck Shipments.* Same as rail.

c. *Marine Vessel Shipments.* Same as rail.

d. *Aircraft Shipments.* Fatigue failures of equipment, caused by components being vibrated at or near their resonant frequency, are common. Steady-state vibrations at frequencies in the range of from 10 to 500 Hz are prevalent. The magnitude of the shocks to which the equipment is subjected is much less than in other applications, and the shock requirements become a secondary factor.

# CHAPTER 2
# INVENTORY OF ARMY MISSILES AND ROCKETS, AND THEIR CONTAINERS

*Data are presented on Army missiles and rockets, and their containers.*

The effectiveness of any container design effort is dependent upon the availability of adequate and accurate data relating to the item to be protected. These data shall include:

a. Detailed geometric outline dimensions
b. Weight
c. Location of center of gravity
d. Maximum allowable vibration and shock loads
e. Support points with corresponding allowable loads
f. Load factors (computed from structural analysis)
g. Susceptibility to environmental hazards including pressure vibrations
h. Pertinent electronic or magnetic characteristics
i. Frequency and degree of periodic inspection and maintenance requirements
j. Test and checkout facilities
k. Military characteristics and logistical support plans of the system
l. Characteristics of any applicable aircraft, marine vessel, or land-based vehicle peculiar to the logistic support plan
m. Projected storage life
n. Degree of permissible disassembly which will not require special skills or tools
o. Other pertinent significant data.

The missile developer shall be required to provide these data to the container designer and shall be further required to advise of all changes subsequent to initial release.

Table 2-1 presents, in ready reference form, data relating to Army missiles and rockets encompassed within the scope of this handbook.

Table 2-2 orients the designer in the current state of the art and serves as an historical record of previous design effort of Army missile and rocket containers.

A cursory review is sufficient to impress one with the need for a standardized design approach, if not a standard modular design capable of convenient spatial modification. Obviously, the result of such an ambitious program will be a compromise; however, the design effort should strive for the ideal container providing:

a. Adequate performance
b. Multifunctional utility
c. Simplicity
d. Durability
e. Minimum cost.

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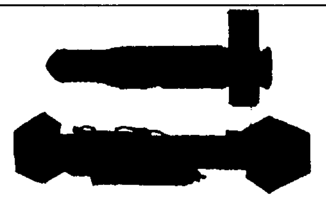
## TABLE 2-1
## DATA RELATING TO CURRENT ARMY MISSILES AND ROCKETS

| MISSILE OR ROCKET | PROFILE | DIMENSIONS O.A., IN. LENGTH | DIA. | SPAN | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | MISSILE DRAWING NUMBERS | MFG. (PRIME) | MISSILE SECTION & DRWG. NO. | CONTAINER USED | DIMENSIONS, IN. LENGTH | DIA. | SPAN | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | TEMPERATURE LIMITS | PRESSURE LIMITS | HUMIDITY LIMITS | FRAGILITY LEVELS | ALLOWABLE BENDING MOMENT | HARD POINTS | HANDLING DEVICES | FINS | LOGISTIC REQUIREMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHILLELAGH |  | APPROX 40 | APPROX 6 | NOT AVAIL. | (C) | 19-1/4 FROM AFT END | (C) | FORD AERONUTRONIC | COMPLETE MISSILE | MODULAR TYPE ALUM. CONTAINER DRAWING NO. 8034969 | APPROX 40 | APPROX 6 | NOT AVAIL. | (C) | 19-1/4 FROM AFT END | (C) | NONE | (C) | 100 G's LONGITUDINAL<br>40 G's TRANSVERSE | 10,000 IN.•LB MAX. | (C) | HAND CARRIED | 4 STRAIGHT COLLAPSIBLE FINS | WORLDWIDE |
| REDEYE LAUNCHER (CONTAINS MISSILE) M41A2<br><br>M41A3 |  | MISSILE: 44<br>LAUNCHER: N/A | MISSILE: 2.75<br>LAUNCHER: N/A | MISSILE: (C)<br>LAUNCHER: N/A | MISSILE: 21.6<br>LAUNCHER: N/A | 21.6 FROM FWD CAP | MISSILE: 10211273<br>IN LAUNCHER: 10211287<br>SYSTEM: 10211285<br><br>MISSILE: 10662274<br>IN LAUNCHER: 10211287<br>SYSTEM: 10662273 | GENERAL DYNAMICS | COMPLETE MISSILE IN LAUNCHER (MISSILE 10211273)<br><br>COMPLETE MISSILE IN LAUNCHER (MISSILE 10662274) | M585 10226996 OR M571 10215052 | MISSILE: 44<br>LAUNCHER: N/A | MISSILE: 2.75<br>LAUNCHER: N/A | MISSILE: (C)<br>LAUNCHER: N/A | MISSILE: 21.6<br>LAUNCHER: N/A | 21.6 FROM FWD CAP | +165°F TO -65°F | 15.4 PSI TO 10.8 PSI | 95% RH @ +85°F-20 H<br>100% RH @ +80°F-4 H | VIB: 2-29 Hz, IG PEAK 29-50 Hz.<br>50-500 Hz 4 G's PEAK ANY AXIS 1 H | 1300 IN.•LB @ 20.125 FROM FRONT | 15.5, 20.12 AND 40 IN. FROM FRONT | NONE | LAUNCHER: NONE<br>MISSILE: (C) | WORLDWIDE PALLETIZED AIR DROPS |
| DRAGON | <br>(LAUNCHER INCLUDING ROUND) | MISSILE: 29.39<br><br>ROUND 45.41<br><br>LAUNCHER | MISSILE: 5.00<br><br>ROUND 11.50<br><br>LAUNCHER | MISSILE: 12.70<br><br>ROUND N/A<br><br>LAUNCHER | 13.45<br><br>25.23<br><br>11.12 (INERT) | 15.89 FROM FWD END<br><br>21.23 FROM FWD END OF TUBE<br><br>22.29 (INERT) | MISSILE: 10275891<br><br>LAUNCHER 10275893 | McDONNELL DOUGLAS | COMPLETE MISSILE IN LAUNCHER<br><br>(ROUND) 10695150 | WOODEN & FIBERBOARD BOXES | MISSILE: 29.39 | MISSILE: 5.00 | MISSILE: 12.70 | 13.45<br>25.23 WITH LAUNCHER | 21.23 FROM FWD END OF LAUNCH TUBE | -65° TO +155°F | 14.7 TO 2.47 PSIA<br>0-40,000 FT | NONE | 45 G's IN ALL DIRECTIONS | UNKNOWN | N/A | WEBBING STRAP (HAND CARRIED) | LAUNCHER: NONE<br><br>MISSILE: 3 | WORLDWIDE |
| TOW LAUNCHER EXTENDER (CONTAINS MISSILE) |  | 50-7/16 | 8-1/2 | N/A | 42 | GEOMETRIC CENTER (25-7/32 FROM END) | DEVELOPMENT STAGE | HUGHES | COMPLETE MISSILE IN LAUNCHER EXTENDER | WIRE-BOUND BOX | 50-7/16 | 8-1/2 | N/A | 42 | GEOMETRIC CENTER 25-7/32 FROM END | -65°F TO +165°F | SEA LEVEL TO 10,000 FT | NONE | CAN WITHSTAND 100 G's 10 ms. 1/2 SINE WAVE, ALL DIRECTIONS | NOT DETERMINED | RIGID ROUND TUBE | WEBBING STRAP (HAND CARRIED) | NONE | WORLDWIDE |
| 2.75-IN. ROCKET |  | | | | | | | NAVY DEVELOPMENT | | | | | | | | | | | | | | | | |
| H161 HE/PD | | 52.8 | 2.75 | N/A | 21.3 | N/A | 922807 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H459 FLECHETTE | | 54.6 | 2.75 | N/A | 20.2 | N/A | 9242070 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H471 HE/RS | | 54.0 | 2.75 | N/A | 21.4 | N/A | 9220807 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H489 HE/PROX | | 54.7 | 2.75 | N/A | 20.4 | N/A | 9220807 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H490 HE/PD | | 52.8 | 2.75 | N/A | 20.2 | N/A | 9220807 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H519 WP | | 52.8 | 2.75 | N/A | 20.2 | N/A | 9252830 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H826 HEDF | | 55.5 | 2.75 | N/A | 20.2 | N/A | 9271017 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |

(C) = CLASSIFIED INFORMATION
N/A = NOT APPLICABLE

(2.75-IN. ROCKET cont'd on next page)

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# TABLE 2-1 (cont'd)

| MISSILE OR ROCKET | PROFILE | DIMENSIONS O.A., IN. LENGTH | DIA. | SPAN | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | MISSILE DRAWING NUMBERS | MFG. (PRIME) | MISSILE SECTION & DRWG. NO. | CONTAINER USED | DIMENSIONS, IN. LENGTH | DIA. | SPAN | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | TEMPERATURE LIMITS | PRESSURE LIMITS | HUMIDITY LIMITS | FRAGILITY LEVELS | ALLOWABLE BENDING MOMENT | HARD POINTS | HANDLING DEVICES | FINS | LOGISTIC REQUIREMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.75-IN. ROCKET (cont'd) |  | | | | | | | | | | | | | | | | | | | | | | | |
| H828 PRACTICE | | 52.8 | 2.75 | N/A | 20.2 | N/A | 9276649 | | N/A | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28.0 | 27 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235841 | 60-1/8 | 20 | 23-3/4 | 105.0 | 26.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H488 HE/PROX | | 64.7 | 2.75 | N/A | 28.2 | N/A | 9220806 | | N/A | 9230116 | 74-7/8 | 8-3/4 | 9-1/2 | 32.0 | 31 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235840 | 70 | 20 | 23-3/4 | 115.0 | 30.5 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9224843 | 46-3/8 | 11-7/8 | 9-9/32 | 27.0 | 19.5 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H534 HE/PD | | 62.8 | 2.75 | N/A | 28.0 | N/A | 9220806 | | N/A | 9230116 | 74-7/8 | 8-3/4 | 9-1/2 | 32.0 | 31 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9235840 | 70 | 20 | 23-3/4 | 115.0 | 30.5 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| | | | | | | | | | N/A | 9224843 | 46-3/8 | 11-7/8 | 9-9/32 | 27.0 | 19.5 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H116 SMOKE | | 62.9 | 2.75 | N/A | 19.6 | N/A | 90-1-332 | | N/A | 9230116 | 74-7/8 | 8-3/4 | 9-1/2 | 32.0 | 31 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H487 HEAT | | — | 2.75 | N/A | — | N/A | 1350663 | | N/A | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | — | — | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H490 HE/PD | | 52.8 | 2.75 | N/A | 20.2 | N/A | 9220807 | | N/A | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | — | — | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H519 WP | | 52.8 | 2.75 | N/A | 20.2 | N/A | 9252830 | | N/A | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | — | — | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H788 RED MARKER | | — | 2.75 | N/A | — | N/A | — | | N/A | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | — | — | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H789 YELLOW MARKER | | — | 2.75 | N/A | — | N/A | — | | N/A | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | — | — | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| H180 FLARE | | 67.9 | 2.75 | N/A | 21.7 | N/A | 11508637 | | N/A | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | — | — | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| ALL TYPES IN BARREL PACK | | — | 2.75 | N/A | — | N/A | — | | N/A | 9335649 | 70-3/4 | 17-1/2 | 17-1/2 | 55.0 | 30.75 FROM NOSE | -65°F TO +165°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | N/A | INTEGRAL PART OF MOTOR | NOT AVAIL. |
| STINGER (LAUNCHER CONTAINS MISSILE) |  | WITH LAUNCHER: 60 MISSILE: 54 | N/A | N/A | 34 | 24 FROM NOSE | 11486951 | GENERAL DYNAMICS | 11567549 | ALUM. | WITH LAUNCHER: 60 MISSILE: 54 | 2.75 | 6.63 | 34 | 26 FROM NOSE | -50°F TO +160°F | TRANS: 0-40,000 FT OPERATION: 0-10,000 FT | MIL-STD-810, METHOD 507, PROCEDURE V | 150 G's HALF SINE PULSE, 10-ms DURATION ALONG MAJOR AXIS | N/A | N/A | NONE | 4 FOLDING | WORLDWIDE |
| | | WITH LAUNCHER: 60 MISSILE: 54 | 2.75 | 6.63 | 26 | 26 FROM NOSE | 11486951 | GENERAL DYNAMICS | 11567549 | WIRE-BOUND BOX | WITH LAUNCHER: 60 MISSILE: 54 | N/A | N/A | 26 | 24 FROM NOSE | -50°F TO +160°F | TRANS: 0-40,000 FT OPERATION: 0-10,000 FT | MIL-STD-810, METHOD 507, PROCEDURE V | 150 G's HALF SINE PULSE. 10-ms DURATION ALONG MAJOR AXIS | N/A | N/A | NONE | 4 FOLDING | WORLDWIDE |
| HELLFIRE (LASER) |  | 64 | 7 | 12.5 WINGS | 96 | 32 FROM NOSE | 13007350 | PRIME ROCKWELL | COMPLETE MISSILE | 13009276 | 75.8 | 17.25 | 19.1 | 68 | 38 | -50°F TO +160°F | PROTECTED TO PRESSURES 37,000 FT ABOVE SEA LEVEL | 5% AT 70°F TO 160°F 100% AT -50°F TO +160°F | 100 G's | 461 N•m | N/A | NONE | 4 WINGS SPAN 12.8 IN. 4 FINS SPAN 10 IN. | NONE |
| CHAPARRAL |  | 115 | 5 | WINGS: 25 x 25 FINS: 16 | (C) | (C) | 1569726 XM1M 72A & 2604974 XM1M 72B | NAVAL AIR SYSTEMS COMMAND | COMPLETE MISSILE | 11074804 | 114.5 | 5 | WINGS 23 ROLLER-ONS: 25 FINS: 16.5 | 190 | (C) | STORAGE: -65°F TO +165°F OPERATION: -65°F TO +165°F | (C) | (C) | (C) | (C) | N/A | NONE | 4 WINGS: 2-1569701 2-1569711 4 FINS: 269631 | (C) |

(C) = CLASSIFIED INFORMATION
N/A = NOT APPLICABLE

(cont'd on next page)

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## TABLE 2-1 (cont'd)

| MISSILE OR ROCKET | PROFILE | DIMENSIONS O.A., IN. | | | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | MISSILE DRAWING NUMBERS | MFG. (PRIME) | MISSILE SECTION & DRWG. NO. | CONTAINER USED | DIMENSIONS, IN. | | | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | TEMPERATURE LIMITS | PRESSURE LIMITS | HUMIDITY LIMITS | FRAGILITY LEVELS | ALLOWABLE BENDING MOMENT | HARD POINTS | HANDLING DEVICES | FINS | LOGISTIC REQUIREMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LENGTH | DIA. | SPAN | | | | | | | LENGTH | DIA. | SPAN | | | | | | | | | | | |
| MULTIPLE LAUNCH ROCKET SYSTEM (MLRS) |  | 155 | 8.94 | 21.8 | 682.6 | 83.6 FROM FRONT OF ROCKET | 13024134 | VOUGHT | WARHEAD: 13029540 MOTOR: 13026895 | LAUNCH POD/ CONTAINER | N/A | N/A | N/A | N/A | N/A | STORAGE & TRANS: -30°F TO +160°F OPERATION: -25°F to +140°F | OPERATION: TO 10,000 FT ABOVE SEA LEVEL. AFTER TRANS: TO 40,000 FT ABOVE SEA LEVEL. DURING FLIGHT: TO 50,000 FT ABOVE SEA LEVEL | AR 70-38, CATEGORIES 1-6 | 19.5 G's FORE & AFT 18.7 G's VERTICAL & LONG (AT LP/C CG) | 83,260 IN.•LB (YIELD) 143,090 IN.•LB (ULTIMATE) | NOT AVAIL. | LAUNCHER-LOADER | 4 FOLDING, CURVED FINS | NOT AVAIL. |
| HAWK (BASIC) XM1M-23A |  | 198 | 14 | 47.4 | 1275 | 122.5 FROM NOSE | J-907175 5 | RAYTHEON | ASSEMBLED W/H & BODY SECTIONS J-907175 5 XM 3E1 | TACTICAL CONTAINER M611 8035841 | 198 | 14 | 47.4 | 1275 | 122.9 FROM NOSE | (C) | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | 4 FINS SHIPPED DETACHED IN XM 430 | WORLDWIDE |
| | | | | | | | | | BODY SECTION XM 22 9069896 | XM 417 E2 J-9073975 | (C) | 14 | N/A | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | NONE | WORLDWIDE |
| | | | | | | | | | WARHEADS: XM5E3-H.E. XM9E2-EXR. XM10E2-INERT | 8837892 AND 8830879 | (C) | 14 | N/A | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | NONE | WORLDWIDE |
| | | | | | | | | | BODY SECTION AFT 9069897 | XM 430 9073970 | (C) | 14 | 47.4 | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | 4 FINS | WORLDWIDE |
| HAWK (IMPROVED) M1M-23B | | 198 | 14 | 47.4 | 1395 | 120.4 FROM NOSE | M1M-23B 10292261 | RAYTHEON | ASSEMBLED W/H & BODY SECTIONS M1M-23B 10292261 | M611 8035841 | 198 | 14 | 47.4 | 1395 | APPROX 120.4 FROM NOSE | STORAGE: -40°F TO +150°F OPERATION: -25°F TO +105°F | (C) | (C) | N/A | N/A | GIMBAL RING CENTER WING RING | HOISTING BEAM | 4 FINS SHIPPED DETACHED IN XM 430 | WORLDWIDE |
| | | | | | | | | | BODY SECTION FORE XM 5 SERIES XM 6 SERIES | 9073975 XM 417 E2 | 122.67 | 14 | N/A | 171 | 60 | STORAGE: -40°F TO +150°F OPERATION: -25°F TO +105°F | (C) | (C) | N/A | N/A | (C) | N/A | N/A | WORLDWIDE |
| | | | | | | | | | WARHEADS: XM 155 SERIES | 8850104 XM 467 | (C) | 14 | N/A | 160 | 80.8 | STORAGE: -40°F TO +150°F OPERATION: -40°F TO 140°F | (C) | (C) | N/A | N/A | (C) | N/A | N/A | WORLDWIDE |
| | | | | | | | | | ROCKET MOTOR XM 112 10242870 | WOODEN BOX INTERIM | 109 | 14 | N/A | 870.6 | 134.7 | STORAGE: -40°F TO 150°F OPERATION: -25°F TO +125°F | (C) | (C) | N/A | N/A | (C) | N/A | N/A | WORLDWIDE |
| LANCE (NUCLEAR) |  | 242 | 22 | 60 | 2850 | STA. 158 (155 FROM FWD END) | 10245800 | VOUGHT | M5 MISSILE MAIN ASSEM-BLAGE 10295810 | M599 | 146 | 22 | N/A | 2360 | STA.177 (77 FROM FWD END) | STORAGE: -65°F TO +155°F | NONE | NONE | NOT AVAIL. | NOT AVAIL. | STA.112 & STA. 224 | M22 SLING | M29 (4 EA.) | WORLDWIDE |
| | | | | | | | | | M234 WARHEAD 8880001 | M511 | 97 | 22 | N/A | 469 | STA.58.5 (55.5 FROM FWD END) | STORAGE: -65°F TO +155°F | NONE | NONE | NOT AVAIL. | NOT AVAIL. | STA.61.5 & STA.98.5 | M22 SLING | N/A | WORLDWIDE |
| | | | | | | | | | M29 FINS 10245491 | M597 | 62 | N/A | N/A | 19 EA. | N/A | STORAGE: -65°F TO +155°F | NONE | NONE | NOT AVAIL. | NOT AVAIL. | N/A | N/A | — | WORLDWIDE |
| LANCE (NON-NUCLEAR) |  | 242 | 22 | 52 | 3450 | STA.145 (142 FROM FWD END) | 10245800 | VOUGHT | M5 MISSILE MAIN ASSEM-BLAGE 10245810 | M599 | 146 | 22 | N/A | 2360 | STA.177 (77 FROM FWD END) | STORAGE: -65°F TO +155°F | NONE | NONE | NOT AVAIL. | NOT AVAIL. | STA.112 & STA. 224 | M22 SLING | M30 (4 EA.) | WORLDWIDE |
| | | | | | | | | | M251 WARHEAD 9284000 | M544 | 97 | 22 | N/A | 995 | STA.68 (65 FROM FWD END) | STORAGE: -65° TO +155°F | NONE | NONE | NOT AVAIL. | NOT AVAIL. | STA.71.5 & STA.98.5 | M22 SLING | N/A | WORLDWIDE |
| | | | | | | | | | M30 FINS 10245493 | M596 | 49 | N/A | N/A | 16 EA. | N/A | STORAGE: -65°F TO +155°F | NONE | NONE | NOT AVAIL. | NOT AVAIL. | N/A | N/A | — | WORLDWIDE |
| HONEST JOHN |  | M31: 327 XM 50: 298.5 | 30 30 | 104 55.75 | 5913 4307 | STA 190 STA 161 (HEAVY W/H) STA 168 (LIGHT W/H) | 8032200 10048008 | EMERSON ELECTRIC DOUGLAS | WARHEAD (VARIETY OF WARHEAD USED-DATA CLASSIFIED) | LUMBER SHEATHED CONTAINER | 115 | 30 | N/A | 1631 | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | NONE | WORLDWIDE |
| | | | | | | | | | ROCKET MOTOR M31 SERIES ROCKETS INCLUDE MOTORS M31A1, M31A1C M31A2 | 8026321 | 212 | 27.7 | 104 | 4275 | STA. 224 | M31A: 0°F TO +100°F M31A1C, M31A2: 0°F TO +120°F | OPERATES FROM BELOW SEA LEVEL TO 31,500 FT | NO LIMITS | NOT AVAIL. | NOT AVAIL. | STA.134 TO STA. 290 | HANDLING BEAM XM 4 | 4 STRAIGHT FINS | WORLDWIDE |
| | | | | | | | | | ROCKET MOTOR XM 66 (ROCKET) XM 50) | 10048370 | 183 | 30 | 55.75 | 3050 | STA. 204 | -40°F TO +120°F (HAS BLANKET) | SAME AS ABOVE | NO LIMITS | NOT AVAIL. | NOT AVAIL. | STA.134 TO STA. 269 | HANDLING BEAM MODIFIED XM 4 | 4 STRAIGHT FINS | WORLDWIDE |

(C) = CLASSIFIED INFORMATION
N/A = NOT APPLICABLE

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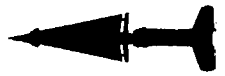
## TABLE 2-1 (cont'd)

| MISSILE OR ROCKET | PROFILE | DIMENSIONS O.A., IN. | | | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | MISSILE DRAWING NUMBERS | MFG. (PRIME) | MISSILE SECTION & DRWG. NO. | CONTAINER USED | DIMENSIONS, IN. | | | WEIGHT, LB | LOCATION OF CENTER OF GRAVITY, IN. | TEMPERATURE LIMITS | PRESSURE LIMITS | HUMIDITY LIMITS | FRAGILITY LEVELS | ALLOWABLE BENDING MOMENT | HARD POINTS | HANDLING DEVICES | FINS | LOGISTIC REQUIREMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LENGTH | DIA. | SPAN | | | | | | | LENGTH | DIA. | SPAN | | | | | | | | | | | |
| PERSHING |  | 408 | 40 | — | 30,000 | NOT AVAIL. | NOT AVAIL. | MARTIN ORLANDO | WARHEAD XM 137 | R-L0565A1 10623212 | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | NONE | WORLDWIDE |
| | | | | | | | | | GUIDANCE & CONTROL XM 474 | R-L0559A2 10625225-9 | (C) | (C) | (C) | NOT AVAIL. | NOT AVAIL. | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | NOT AVAIL. | NONE | WORLDWIDE |
| | | | | | | | | | 2ND STAGE XM 476 | R-L0560B1 10625227-9 | (C) | (C) | (C) | NOT AVAIL. | NOT AVAIL. | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | NOT AVAIL. | 4 FINS SHIPPED SEPARATELY | WORLDWIDE |
| | | | | | | | | | 1ST STAGE XM 475 | R-L0560A1 10625226-9 | (C) | (C) | (C) | NOT AVAIL. | NOT AVAIL. | (C) | (C) | (C) | (C) | (C) | NOT AVAIL. | NOT AVAIL. | 4 FINS SHIPPED SEPARATELY | WORLDWIDE |
| NIKE — HERCULES |  | 498-1/2 | 31-1/2 | MISSILE FINS: 90<br>BOOSTER FINS: 138 | 10,670 | 292 FROM NOSE | | WESTERN ELECTRIC | BODY SECTION (FORE & AFT) 9028253 | M410 9031007 | 262-1/2 | 31-1/2 | 90 | 1329 | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. |
| | | | | | | | | | WARHEAD SECTION | M409 9031006 | 62-1/2 | 31 | N/A | 1230 | (C) | (C) | (C) | (C) | (C) | (C) | (C) | CABLE SLING ORDXR-FMO-987 | NOT AVAIL. | NOT AVAIL. |
| | | | | | | | | | ROCKET MOTOR M42 or M42A1 8525883 (CONSISTS OF FOUR M5E1 OR M88 MOTORS) | 9031177 | 173-1/2 | WIDTH: 35-1/4 HEIGHT: 37 | N/A | 5275 | NOT AVAIL. | STORAGE: -20°F TO +130°F OPERATION: -10°F TO +130°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | SLING ASS'Y 8003041 FOR M5E1 HOIST BEAM 8166439 FOR M42 | 4 ALUM. FINS, SPAN OF 18.7 IN. | NOT AVAIL. |
| | | | | | | | | | ROCKET MOTOR M30 8034272 | 8034264 | 105 | N/A | NOT AVAIL. | NOT AVAIL. | N/A | -20°F TO +125°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | BEAM ASS'Y 8524366 | NOT AVAIL. | NOT AVAIL. |

(C) = CLASSIFIED INFORMATION
N/A = NOT APPLICABLE

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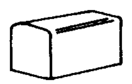
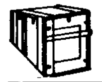
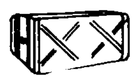
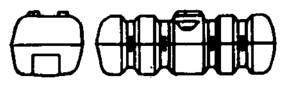
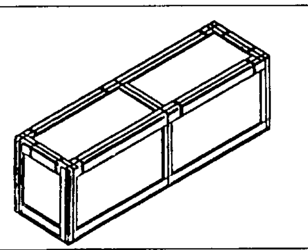
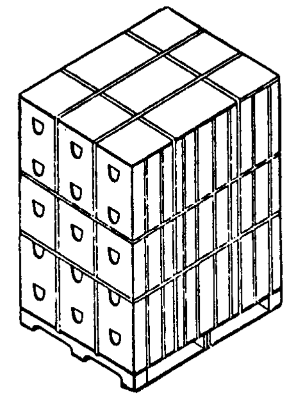
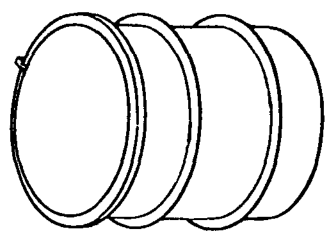
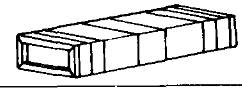
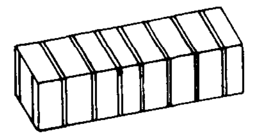
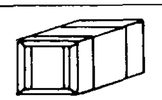
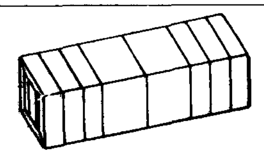
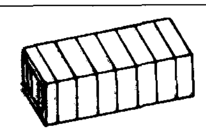
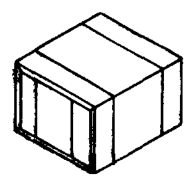
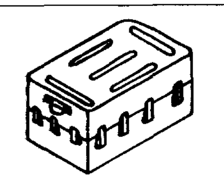
# TABLE 2-2. CURRENT AND HISTORICAL DATA ON CONTAINERS FOR ARMY MISSILES AND ROCKETS

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. | | | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LENGTH | WIDTH | HEIGHT | | | | | | | | | | | | | | | | | | | | | | |
| SS-10 (PHASED OUT) |  | COMPLETE MISSILE (DISASSEMBLED) | NORD AVIATION (FRANCE) | NOT AVAIL. | 22.0 | 22.4 | 23.2 | 55 70.4 WITH LAUNCHER GROSS: 103.4 | ℄ | STEEL | SQUARE | END (BOTH) | BODY SECURED TO SPONGE RUBBER LINED BEAMS. W/H HOUSED IN FELT LINED RECESS | NOT AVAIL. | NONE | NONE | NONE (CONTAINER IS WATER-TIGHT) | NO LIMITS | STACK 4 HIGH | NONE | NONE | HAND GRIP ON EACH SIDE | NONE | CONSTRUCTION OF CONTAINER ALIGNS COVER | RUBBER GASKETS BOTH ENDS | 4 TOGGLE FASTENERS | NONE | REUSABLE WORLDWIDE | NOT AVAIL. |
| SS-11 (PHASED OUT) |  | COMPLETE MISSILE (DISASSEMBLED) | NORD AVIATION (FRANCE) | NOT AVAIL. | 35 | 17 | 23 | 78.2 WITH LAUNCHER | NOT AVAIL. | STEEL | SQUARE | END (BOTH) | BODY SECURED TO SPONGE RUBBER LINED BEAMS. W/H SUPPORTED ON FELT LINED CROSS MEMBERS | UNKNOWN | NONE | NONE | NONE | UNKNOWN | NOT AVAIL. | NONE | NONE | NOT AVAIL. | NONE | NONE | NOT AVAIL. | 4 TOGGLE FASTENERS | NONE | REUSABLE WORLDWIDE | 5 |
| |  | COMPLETE MISSILE (DISASSEMBLED) | NORD AVIATION (FRANCE) | 730.300 | 36.2 | 18.9 | 20.5 | EMPTY: 33 GROSS: 99.2 | UNKNOWN | FIBERGLASS | BASICALLY RECT. | TOP | SPONGE RUBBER PADS SUPPORT MISSILE COMPONENT | UNKNOWN | NONE | NONE | NONE (CONTAINER IS WATER-TIGHT) | UNKNOWN | STACK 4 HIGH FOR STORAGE. 3 HIGH FOR SHIPPING | CONFIGURATION PROVIDES STACKING | CONFIGURATION PROVIDES UNITIZATION | 2 METAL HANDLES BUILT INTO COVER | NONE | ALIGNED BY LIP ON THE COVER | RUBBER GASKET | 8 DRAW-PULL TYPE LATCHES | NONE | REUSABLE WORLDWIDE | 5 |
| |  | COMPLETE MISSILE (DISASSEMBLED) | NORD AVIATION (FRANCE) | NOT AVAIL. | 37.2 | 19.5 | 24.4 | EMPTY: 94.8 GROSS: 156.5 | ℄ | WOOD | RECT. | TWO SIDES TOP & END REMOVABLE | NOT AVAIL. | NOT AVAIL. | NONE | NONE | NONE (WOOD PROTECTED AGAINST FUNGI) | NO LIMITS | STACK 4 HIGH | NONE | NONE | TWO WOODEN HANDLES FRONT & REAR | NONE | NONE | NONE | DRAW-PULL TYPE LATCHES | NONE | EXPENDABLE WORLDWIDE | 5 |
| ENTAC (PHASED OUT) |  | COMPLETE MISSILE (DISASSEMBLED) | NORD AVIATION (FRANCE) | APX/2228-8-10-090 | 28.3 | 12.7 | 13.7 | 55 WITH LAUNCHER GROSS: 82 | UNKNOWN | METAL | RECT. | BOTH ENDS REMOVABLE | RUBBER SHOCK MOUNTS | UNKNOWN | NONE | NONE | DESICCANT (16 UNITS) | NOT AVAIL. | NOT AVAIL. | NONE | NONE | HAND GRIP ON EACH END | NONE | TONGUE AND GROOVE | RUBBER GASKET | 8 DRAW-PULL TYPE LATCHES (4 EACH END) | NONE | REUSABLE WORLDWIDE | 5 |
| SHILLELAGH |  | COMPLETE MISSILE | PROTYPES: ZERO MFG. CO. | EXTENDED RANGE 8034969 | 52.5 | 14 | 14 | 54 | ℄ | ALUM. | SQUARE | END (ONE) | BULK FIBERGLASS SUSPENSION SYS. | 40 G's TRANSVERSE 100 G's LONGITUDINALLY | NONE | SEALED UNPRESSURIZED A.P.R.V. | DESICCANT | -80°F TO +155°F | STACK 5 HIGH | NONE | NONE | HAND GRIP ON EACH END | NONE | NONE | RUBBER GASKET | 4 QUICK RELEASE LATCHES | NONE | REUSABLE WORLDWIDE | 5 |
| REDEYE |  | LAUNCHER CONTAINING MISSILE | GENERAL DYNAMICS | 10226996 | 56.75 | 10 | 15.5 | 19 | ℄ EMPTY | UNICELLUAR POLYETHYLENE FOAM & ALUM. ALLOY | RECT. | TOP SEPARATES IN TWO HALVES | RIGID POLYURETHANE FOAM SUPPORTS POLYETHYLENE FOAM CUSHIONING | 250 G's AT 30-IN. DROP | NONE | NONE | 20 UNITS DESICCANT | -65°F TO +165°F | STACK 7 HIGH | 4 ROUND STACKING DEPRESSION ON BOTTOM & 4 STACKING EXTRUSIONS ON TOP | NONE | 1 HAND GRIP ON TOP HALF IN CENTER | NONE | 2 PLATENS 1 EACH END LOCATED IN INTERIOR OF CONTAINER | WEAPON SEALED IN BARRIER BAG | 8 CAMLOC LATCHES | NONE | DISPOSABLE WORLDWIDE | 5 TO INDEFINITE |
| | | LAUNCHER CONTAINING MISSILE | GENERAL DYNAMICS | 10215052 | 56 | 17.25 | 12.54 | 42.5 | ℄ EMPTY | ALUM. | RECT. | TOP AND BOTTOM HALVES | POLYURETHANE FOAM INSERTS | 300 G's AT 36-IN. DROP | NONE | NONE | RUBBER SEAL AND DESICCANT | -65°F TO +165°F | STACK 7 HIGH | CONVEX/CONCAVE MATING INDENTURES | NONE | HANDLES ON END | NONE | LAPPED EDGES | RUBBER GASKET | 10 CAMLOC LATCHES | HUMIDITY INDICATOR | REUSABLE/RETURNABLE | 15 TO INDEFINITE |
| DRAGON |  | GUIDED MISSILE SURFACE ATTACK (SINGLE ROUND) | REDSTONE ARSENAL | 8035953 | 47-1/2 | 16 | 16 | 41 | ℄ | WOOD | RECT. | TOP | POLYETHYLENE FOAM CRADLES | 45 G's IN ALL DIRECTIONS | NONE | NONE | NONE | NO LIMITS | STACK 5 HIGH | NONE | NONE | ROPE HANDLES (1 EACH END) | NONE | NONE | NONE | 10 SPRING KLIMP FASTENERS | NONE | REUSABLE WORLDWIDE | 8 |
| |  | GUIDED MISSILE SURFACE ATTACK (MULTIPACK 15 ROUNDS) | REDSTONE ARSENAL | 13013761 | 49 | 37-3/4 | 66-3/8 | 280 658 (LOADED) | ℄ | FIBERBOARD & WOOD | RECT. | END (ONE) | POLYETHYLENE FOAM CRADLE | UNKNOWN | NONE | NONE | NONE | NO LIMIT | NOT AVAIL. | NONE | NONE | NONE | WOOD PALLET BASE (4 WAY FORKLIFT ENTRY) | NONE | NONE | WIRE LOOPS | NONE | DISPOSABLE OCCASIONALLY REUSED WORLDWIDE | 8 |

(DRAGON cont'd on next page)

## TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. LENGTH | WIDTH | HEIGHT | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRAGON (cont'd) |  | TRACKER, INFRARED, G.M. SU-36/P | REDSTONE ARSENAL | MS27683-1 | 16-3/8 | 16-3/8 | 21-3/4 | 33.25 | ℄ | STEEL (LOW CARBON) | CYL. | TOP | RUBBERIZED HAIR PADS | 100 G's ALL DIRECTIONS | NONE | NONE | DESICCANT | -65° TO 155°F | NOT AVAIL. | NONE | NONE | NONE | NONE | NONE | RUBBER GASKET | NONE | NONE | REUSABLE WORLDWIDE | 8 |
| TOW |  | LAUNCHER EXTENDER CONTAINING COMPLETE MISSILE | HUGHES AIRCRAFT | NOT AVAIL. | 55 | 19 | 10-1/2 | APPROX. 25 | GEOMETRICAL CENTER | WIRE-BOUND BOX | RECT. | TOP | EXPANDED POLYSTYRENE | 80 G's IN ALL DIRECTIONS | NONE | NONE | NONE | NO LIMITS | STACK 6 HIGH | NONE | NONE | ROPE HANDLES (1 EACH END) | NONE | NONE | NONE | WIRE LOOPS | NONE | EXPENDABLE WORLDWIDE | 5 |
| |  | GUIDED MISSILE, SURFACE ATTACK | | 10224699 | 58.1 | 11.5 | 11.5 | 29.2 | GEOMETRIC CENTER | WOOD | RECT. | TOP | PLYWOOD SADDLE | — | NONE | NONE | VAPOR BARRIER | -65°F TO +155°F | STACK 6 HIGH | NONE | NONE | NONE | NONE | NONE | VAPOR BARRIER BAG | WIRE LOOPS | HUMIDITY INDICATOR BARRIER BAG | EXPENDABLE WORLDWIDE | 5 |
| |  | TRAVERSING UNIT | | 10224693 | 27-7/8 | 25-1/2 | 18 | 20 | GEOMETRIC CENTER | WOOD & FIBERBOARD BOX | RECT. | TOP | PLASTIC FORM CUSHION | — | NONE | NONE | VAPOR BARRIER | -65°F TO +155°F | STACK 6 HIGH | NONE | NONE | NONE | NONE | NONE | VAPOR BARRIER BAG | WIRE LOOPS | NONE | EXPENDABLE WORLDWIDE | 5 |
| |  | LAUNCHER TUBE | | 10224688 | 72-1/4 | 11-1/4 | 11-1/4 | 12.8 | GEOMETRIC CENTER | WOOD | RECT. | TOP | PLYWOOD SADDLE | — | NONE | NONE | VAPOR BARRIER DESICCANT | -65°F TO +155°F | STACK 6 HIGH | NONE | NONE | NONE | NONE | NONE | VAPOR BARRIER BAG | WIRE LOOPS | NONE | EXPENDABLE WORLDWIDE | 5 |
| |  | TRIPOD MOUNT | | 10224681 | 49-3/4 | 14-3/4 | 15-1/4 | 12.5 | GEOMETRIC CENTER | WOOD | RECT. | TOP | PLYWOOD SADDLE | — | NONE | NONE | NONE | -65°F TO +155°F | STACK 6 HIGH | NONE | NONE | NONE | NONE | NONE | VAPOR BARRIER BAG | WIRE LOOPS | NONE | EXPENDABLE WORLDWIDE | 5 |
| |  | MISSILE GUIDANCE SET | | 10224679 | 22-1/4 | 20-3/4 | 14-1/4 | 15.5 | GEOMETRIC CENTER | WOOD | RECT. | TOP | PLASTIC FOAM CUSHION | — | NONE | NONE | VAPOR BARRIER | -65°F TO +155°F | STACK 6 HIGH | NONE | NONE | NONE | NONE | NONE | VAPOR BARRIER BAG | WIRE LOOPS | NONE | EXPENDABLE WORLDWIDE | 5 |
| |  | SIGHT SENSOR | | 10679721 | 32 | 25 | 21-1/2 | 35 | — | ALUM. | RECT. | TOP | ELASTOMERIC SHOCK MOUNTS | 33 G's | — | — | | -65°F TO +155°F | STACK 3 HIGH | NONE | CONFIGURATION PROVIDES UNITIZATION | 2 METAL HANDLES BUILT INTO COVER | NONE | NONE | RUBBER GASKET | 14 DRAW-PULL TYPE LATCHES | NONE | REUSABLE WORLDWIDE | 5 |

(cont'd on next page)

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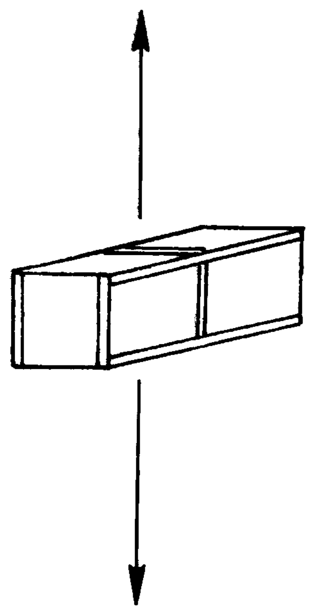
# TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. | | | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LENGTH | WIDTH | HEIGHT | | | | | | | | | | | | | | | | | | | | | | |
| 2.75-IN. ROCKET |  | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H161 HE/PD | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H459 FLECHETTE | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H471 HE/RS | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H489 HE/PROX | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H490 HE/PD | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H519 WP | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H826 HEDP | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H828 PRACTICE | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230114 | 62-7/8 | 8-3/4 | 9-1/2 | 28 | 27 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H116 SMOKE | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230116 | 74-7/8 | 8-3/4 | 9-1/2 | 32 | 31 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H488 HE/PROX | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230116 | 74-7/8 | 8-3/4 | 9-1/2 | 32 | 31 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H534 HE/PD | | ASSEMBLED ROCKETS, 4-PACK | OPEN PROCUREMENT | 9230116 | 74-7/8 | 8-3/4 | 9-1/2 | 32 | 31 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H487 HEAT | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H490 HE/PD | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H519 WP | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H788 RED MARKER | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H789 YELLOW MARKER | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H180 FLARE | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9209570 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H488 HE/PROX | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9224843 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H53 HE/PD | | UNASSEMBLED ROCKETS, 3-PACK | OPEN PROCUREMENT | 9224843 | 46-3/16 | 11-7/8 | 9-9/32 | 27 | 19.5 FROM NOSE | WOOD | RECT. | TOP | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | PALLET | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H161 HE/PD | | ASSEMBLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H459 FLECHETTE | | ASSEMBLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |

N/A = NOT APPLICABLE

(2.75-IN. ROCKET cont'd on next page)

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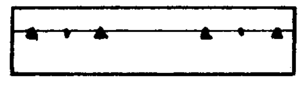
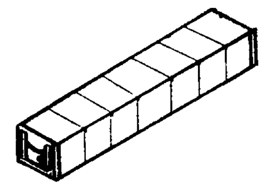
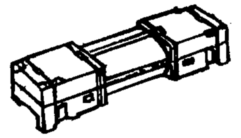
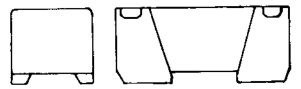
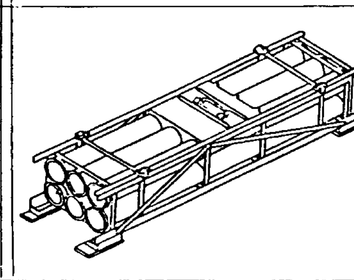
## TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. LENGTH | WIDTH | HEIGHT | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURA-TION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H471 HE/RS | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A |
| H489 HE/PROX | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A |
| H490 HE/PD | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A |
| H519 WP | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A |
| H826 HEDP | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A |
| H828 PRACTICE | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235841 | 60-1/8 | 20 | 23-3/4 | 105 | 23-3/4 FROM NOSE | WOOD | RECT. | END | NONE | N/A |
| H488 HE/PROX | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235840 | — | — | — | — | — | WOOD | RECT. | END | NONE | N/A |
| H534 HE/PD | | ASSEM-BLED ROCKETS, 25-PACK | OPEN PROCUREMENT | 9235840 | — | — | — | — | — | WOOD | RECT. | END | NONE | N/A |
| ALL TYPES | | ASSEM-BLED ROCKETS, 19-PACK | GRIEF BROS. | 9335649 | — | — | — | — | — | STEEL | CYL. | END REMOVE COVER AND LOCKING RING | NONE | N/A |
| STINGER |  | WEAPON ROUND | ZERO | 11486952 | 66.01 | 12.96 | 13.26 | 49 | GEOMETRIC CENTER | ALUM. | BASICALLY RECT. | TOP THIRD HINGED | POLYETHYLENE CUSHIONING | OPERATION AFTER 36-IN. DROP AND TRANSPORTA-TION VIBRA-TION |
| |  | MISSILE ROUND | INTERPAC | 11509503 | 67.25 | 13.12 | 10.50 | 41.3 | GEOMETRIC CENTER | WIRE-BOUND BOX | RECT. | TOP | POLYETHYLENE CUSHIONING | OPERATION AFTER 36-IN. DROP AND TRANSPORTA-TION VIBRA-TION |
| HELLFIRE (LASER) |  | COMPLETE MISSILE | HOLLFORM, INC. | 13009276 | 75.8 | 17.25 | 19.1 | 68 | APPROXIMATELY GEOMETRIC CENTER | CROSS-LINK POLYETHYLENE | RECT. | TOP | POLYETHAFOAM CUSHIONING OF INNER POLY-ETHYLENE COLLAR | 100 G's |
| CHAPARRAL |  | COMPLETE MISSILE XMIM-72A OR AMIM-72B | SPACO, INC. | 11074804 | 125 | 17.75 | 19 | 110 MAX. | APPROXIMATELY GEOMETRIC CENTER | POLYURETHANE & ALUM. | RECT. | BOTH ENDS | SHOCK MOUNTS | 25 G's |
| MULTIPLE LAUNCH ROCKET SYSTEM (MLRS) |  | 6 COMPLETE MISSILES | VOUGHT CORP. | 13027900 | 166 | 42 | 33 | 871 | 82.8 FROM FRONT END | ALUM. & FIBERGLASS | RECT. | N/A | 4 EXTERNAL ELASTOMERIC SHOCK MOUNTS | 19 G's |

| MISSILE OR ROCKET | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H471 HE/RS | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H489 HE/PROX | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H490 HE/PD | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H519 WP | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H826 HEDP | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H828 PRACTICE | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H488 HE/PROX | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| H534 HE/PD | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | NONE | INTEGRAL SKID | N/A | INTEGRAL SKID | N/A | NONE | STEEL STRAPPING | N/A | EXPENDABLE | 10 |
| ALL TYPES | NONE | NONE | NONE | STORAGE: -65°F TO +165°F OPERATION: -40°F TO +165°F | STACK 5 HIGH | ON PALLET | ON PALLET | N/A | ON PALLET | N/A | RUBBER GASKET | STEEL STRAPPING | N/A | REUSABLE | 10 |
| STINGER | NONE | NONE | WATERTIGHT PLUS DESICCANT BREATHER | -50°F TO +160°F | STACK 5 HIGH TRANSPORTA-TION; 9 HIGH STORAGE | NONE | NONE | 2 FOLDING HANDLES | NONE | TONGUE AND GROOVE | RUBBER GASKET | 4 HALF-TURN LATCHES | HUMIDITY INDICATOR | REUSABLE/ WORLDWIDE | 10 |
| | NONE | NONE | SEALED VAPOR BARRIER PLUS DESICCANT | -50°F TO +160°F | STACK 6 HIGH TRANSPORTA-TION; 9 HIGH STORAGE | NONE | NONE | ROPE HANDLES BOTH ENDS | NONE | NONE | VAPOR BARRIER BAG | WIRE LOOPS | HUMIDITY INDICATOR | EXPENDABLE/ WORLDWIDE | 10 |
| HELLFIRE (LASER) | -50°F TO +160°F | PROTECTED TO PRESSURES 37,000 FT ABOVE SEA LEVEL | NONE | -50°F TO +160°F | STACK 10 HIGH | MOLDED IN NESTING PROVISIONS | N/A | 4 HANDLES (ALUM.); 4 HANDLES (MOLDED IN); FORKLIFT ACCOMMODA-TIONS | NONE | NONE | NONE | POLYESTER STRAPS | NONE | EXPENDABLE WITH SOME REUSABLE CAPABILITY | 10 |
| CHAPARRAL | -65°F TO +165°F | NONE | SEALED TUBE | -65°F TO 165°F | STACK 3 HIGH | NONE | NONE | 4 HANDLES (2 PER END) AND FORKLIFT ACCOMMODA-TIONS | NONE | NONE | RUBBER SEAL BETWEEN TUBE COVER AND TUBE | WING NUTS ON INNER TUBE AND SKIN FLUSH LATCHES (2 PER END) | NONE | EXPENDABLE WITH SOME REUSABLE CAPABILITY | 5 |
| MULTIPLE LAUNCH ROCKET SYSTEM (MLRS) | NONE | 22 PSI | SEALED TUBE | OPERATION: -25°F TO +140°F STORAGE: -30°F TO +168°F | STACK 2 HIGH IN TRANSIT; 4 HIGH IN STORAGE. | 4 STACKING PINS | NONE | 4 LIFT RINGS FORKLIFT | 4 ELASTOMERIC SHOCK ISOLATORS | N/A | MIL-S-8802 CLASS B-2 ADHESIVE, COVER TO TUBE | N/A | NONE | EXPENDABLE | 10 |

N/A = NOT APPLICABLE

(cont'd on next page)

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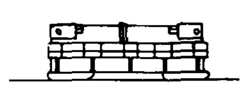
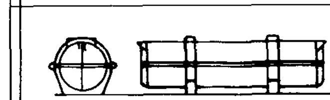
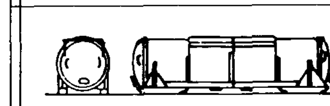
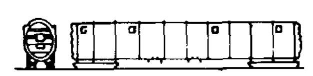
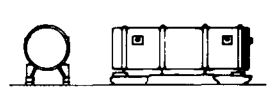
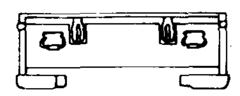
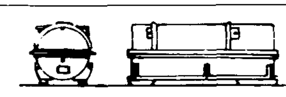
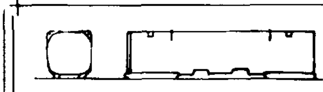
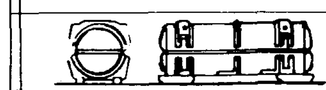
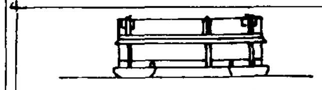
## TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. | | | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LENGTH | WIDTH | HEIGHT | | | | | | | | | | | | | | | | | | | | | | |
| LITTLE JOHN (PHASED OUT) |  | WARHEADS: M-8; M50 M78; M146 M206 | DESIGN: PICATINNY & G.E. MFG: CHAMPION | M477 F-8834100 | 100 | 28-3/8 | 34-1/4 | 1102 | NOT AVAIL. | STEEL | OVAL | TOP | 4 or 6 ELASTOMERIC MOUNTS DEPENDING ON TYPE OF WARHEAD | 20 G's | NONE | SEALED DESIGNED TO WITHSTAND 15 PSI INTERNAL | DESICCANT (40 UNITS) LESS THAN 30% RH | -65°F TO +130°F | NOT STACKED WHEN LOADED | 4 STACKING PADS ON COVER | UNITIZED BY 4 STEEL STRAPS | LIFTING POINTS ON COVER TIE-DOWNS & TOWING EYES ON BASE | 4 LONGITUDINAL WOOD SKIDS | ALIGNED BY LIP ON BASE | RUBBER GASKET | 20 CAMLOC LATCHES (37L) | HUMIDITY INDICATOR RELIEF VALVES | REUSABLE | 10 |
| |  | ROCKET MOTOR (318 mm) M26 J8533020 | CONSOLIDATED WESTERN STEEL | XM 455 8533079 | 124-3/4 | 44 | 38-11/16 | 860 | EMPTY: ℄ | STEEL | CYL. | TOP | 4 BROAD TEMP. RANGE ELASTOMERIC SHEAR MOUNTS 8848655 | 40 G's IN ALL DIRECTIONS | NONE HAS BLANKET XM 5E1 59C32 | NONE | NONE | -65°F TO +130°F | STACK 3 HIGH | 2 TRANSVERSE STACKING PADS | 4 STRAPS CONNECTING SKID TO STACKING PAD | 2 FITTINGS ON ENDS OF COVER 4 FITTING ON FRAME AT ℄ FOR LIFTING ENTIRE CONT. | 2 TRANSVERSE METAL SKIDS (PART OF FRAME) APPROX. 6 IN.×24 IN. AREA 144 IN.²/SKID | 2 PINS ONE ON EACH END AT ℄ | NO SEALING (PROVIDED WITH DRAIN HOLES) | HANDKNOBS (50) | NONE | REUSABLE | NOT AVAIL. |
| |  | ROCKET MOTOR (318 mm) M26 J8533020 | MODIFIED BY PUEBLO ARMY DEPOT | M498 8034708 (MODIFIED) NIKE CONTAINER | 13! | 38 | 41 | 1560 | NOT AVAIL. | STEEL | CYL. | END (BOTH) | ELASTOMERIC MOUNTS (4) 8034716 | 40 G's IN ALL DIRECTIONS | NONE | 5 PSIG (TESTED AT 20 PSIG) PRESSURIZATION DROPPED IN 1963 | DESICCANT (40 UNITS) LESS THAN 30% RH | -65°F TO +130°F | STACK 3 HIGH | 4 STACKING PADS ON ANGLE RING AROUND BODY | 4 STRAPS CONNECT STACKING PAD TO FRAME | 4 LIFT EYES ON SIDE OF BODY; 2 HAND GRIPS ON COVERS, FORK CHANNELS AT ℄ TRANS. | 4 WOODEN SKIDS 42 IN.× 3-5/8 IN. LONGITUDINAL (8034707) AREA 144 IN.²/SKID | 1 PIN ON BODY (EACH END) | SYNTHETIC RUBBER GASKET ON EACH END | 8 BOLTS (EACH END) | HUMIDITY INDICATOR | REUSABLE | NOT AVAIL. |
| | (CONTAINER OBSOLETE) | ROCKET MOTOR (XM26E1) W/ OR W/O | NOT AVAIL. | 62170-00-39 | 161 | 24 | 31 | GROSS: 1675 | NOT AVAIL. | WOOD | RECT. | TOP AND SIDES REMOVABLE | NOT AVAIL. | NOT AVAIL. | NONE | NONE | NONE | NO LIMITS | NOT AVAIL. | NONE | NONE | NOT AVAIL. | LONGITUDINAL WOODEN SKIDS | NONE | NONE | BOLTS | NONE | EXPENDABLE | — |
| HAWK & IMPROVED HAWK |  | COMPLETE MISSILE XM1M-23A OR M1M-23B, MOTOR SECTION XM 22 AND FOUR FINS | R & D APPLIED DESIGN PRODUCTION WILLIAMSON MFG. CO. | M611 8035841 | 216 | 26-3/4 | 41-1/2 | 1950 | EMPTY: 111-3/16 FROM CLOSED END. LOADED: 121-5/16 FROM CLOSED END | STEEL | OVAL | END (ONE) | 20 ELASTOMERIC MOUNTS ARMY 9198717 8 SHOCK ABSORBERS ORD 9198714 | LONGITUDINALLY: 25 G's FROM 160°F TO -40°F ALL OTHER DIRECTIONS: 26 G's FROM 160°F TO -25°F | NONE | SHIPPED & STORED AT 2-1/2 ±½ PSIG CONTAINER TESTED AT 7 PSIG. AIR SHIPPED DEPRESSURIZED | DESICCANT | STORAGE LIMITS: -40°F TO +140°F | 6700 LB (TOTAL) | 4 STACKING PADS ON CORNERS OF BODY | 4 STEEL STRAPS ON SIDES CONNECT STACKING PAD TO BODY FRAME ABOVE SKID | TRANSVERSE FORK CHANNELS 4 LIFT PTS. ON BRK'S ON TOP OF BODY TOWING HOLES NEAR SKIDS HAND GRIPS ON COVER | 4 WOODEN SKIDS LOCATED IN FOUR CORNERS ORD 9198700-1&2 | 3 TAPERED PINS ON CONTAINER | RUBBER GASKET | 12 'T' HEAD BOLTS | HUMIDITY INDICATOR | REUSABLE | 5 YR IN STORAGE 1 YR FIELD MIN. OF 20 OPENINGS |
| |  | FORE BODY SECTION I.E. GUIDANCE SECTION | SEE ABOVE | XM 417 E2 9073975 | 89-9/16 | 28-21/32 | 33-5/16 | 555 | EMPTY: 47 FROM CLOSED END, LOADED: 51 FROM CLOSED END | STEEL | CYL. | END (ONE) | 8 HELICAL COMP. SPRINGS 9082015 & 9082016 RUBBER BUMPERS 9082043 | LONGITUDINALLY: 30 G's FROM -65°F TO 160°F ALL OTHER DIRECTIONS: 20 G's FROM -65°F TO 160°F | NONE | SHIPPED & STORED AT 2-1/2 PSIG DEPRESSURIZED PRIOR TO AIR SHIPMENT TESTED AT 15 PSI | DESICCANT | NOT AVAIL. | STACK 4 HIGH | SAME AS ABOVE | SAME AS ABOVE | 4 LIFT PTS ON BRK'S ON TOP OF BODY TOWING HOLES NEAR SKIDS HAND GRIPS ON COVER | 4 LONGITUDINAL WOOD SKIDS 9082029 9082042 | 2 TAPERED PINS ON CONTAINER BODY | RUBBER GASKET | 10 'T' HEAD BOLTS 9082040 | HUMIDITY INDICATOR 9082044 RELIEF VALVE 8134499 | REUSABLE | SAME AS ABOVE |
| |  | WARHEAD (ALL TYPES) ONE PER BOX | PICATINNY ARSENAL | 8837892 | 18-1/16 | 18-1/16 | 17-29/32 | 38 GROSS: 157 | ℄ | LUMBER SHEATHED | RECT. | TOP & SIDES REMOVED AS A UNIT | THIN CUSHIONING PAD USED UNDER WARHEAD | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | NOT AVAIL. | NONE | NONE | NONE | NONE | CONSTRUCTION OF BOX ALIGNS TOP AND SIDES | NONE | CAP SCREWS | NONE | DISPOSABLE WORLDWIDE | — |
| |  | WARHEAD (ALL TYPES) TWO PER BOX | PICATINNY ARSENAL | 8830879 | 32-15/16 | 18-1/16 | 21-17/32 | 83 GROSS: 304 | ℄ | LUMBER SHEATHED | RECT. | TOP & SIDES REMOVED AS A UNIT | THIN CUSHIONING PAD USED UNDER WARHEAD | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | NOT AVAIL. | NONE | NONE | NONE | 3 TRANSVERSE WOOD SKIDS | CONSTRUCTION OF BOX ALIGNS TOP AND SIDES | NONE | CAP SCREWS & 2 STEEL STRAPS | NONE | DISPOSABLE WORLDWIDE | — |
| |  | WARHEAD XM 155 SERIES | PICATINNY ARSENAL | 8850104 | 57 | 22 | 20.5 | 110 | NOT AVAIL. | ALUM. W/WOOD SKIDS | RECT. | TOP | RESILIENT MOUNTS | TRANSVERSE 60 G's SIDE DIRECTIONS LONGITUDINAL 250 G's 4-FT DROP | -40°F TO +140°F | 1.70 ±1.5 PSI MIN. CRACKING 1.10 TO 1.70 PSI CLOSE 1.00 TO 0.15 PSI | DESICCANT | -40°F TO 140°F | STACK 3 HIGH | 4 STACKED PROTRUSIONS ON TOP & 4 TIE DOWN RINGS | NONE | LIFTING HANDLES 2 EACH SIDE 2 TOW RINGS 1 EACH END | 4 LONGITUDINAL WOOD SKIDS | N/A | RUBBER GASKET | 8 LATCHES 2 EACH SIDE 2 EACH END | N/A | REUSABLE WORLDWIDE | 5 |
| LACROSSE (PHASED OUT) |  | WARHEAD M139 | PICATINNY ARSENAL | 8838740 XM 471 | 96 | 35 6 | 38 6 | 649 GROSS: 1200 | EMPTY: ℄ LOADED: 37-1/4 FROM AFT END | STEEL | CYL. | TOP | 8 ELASTOMERIC MOUNTS | NOT AVAIL. | NONE | BUILT TO STAND 5 PSIG PRESSURIZATION. DROPPED BECAUSE IT WAS IMPRACTICABLE TO MAINTAIN PRESSURE BETWEEN 0.5 & 2.7 PSI | DESICCANT (10 LB) | NOT AVAIL. | STACK 4 HIGH. OUTDOOR STORAGE ONLY 2 HIGH | 4 STACKING PADS ON COVER | FOUR 1-1/4×0.035 STEEL STRAPS CONNECT STACKING PADS TO BRK. ON CONTAINER | 2 LIFTING RINGS ON COVER TIE-DOWNS & TOW HOLES IN FRAME | 4 LONGITUDINAL WOOD SKIDS | 6 PINS ON BOTTOM HALF OF CONTAINER | SEALED BY O-RING | 24 'T' BOLTS & LOCK NUTS | HUMIDITY INDICATOR EQUALIZATION PLUG | REUSABLE | NOT AVAIL. |
| |  | BODY ASSEMBLY W/MOTOR XM 4E2 W/WING & FINS | NOT AVAIL. | XM 374E2 XM 374E1 8901400 | 182 | 41 | 45 | 1576 GROSS: 3974 | EMPTY: ℄ LOADED: 87-1/4 FROM OPEN END | STEEL | RECT. | END (ONE) | ELASTOMERIC MOUNTS | NOT AVAIL. | NONE | | DESICCANT (14 LB-224) UNITS) | STORAGE LIMITS: -60°F TO +140°F | STACK 3 HIGH | 4 STACKING PADS ON TOP OF BODY | NONE | 4 LIFT PTS. ON TOP OF BODY. 2 HAND GRIPS ON COVER. BODY NOTCHES FOR FORK TINES | 4 LONGITUDINAL WOOD SKIDS | 2 PINS ON BODY OF CONTAINER | SEALED BY GASKET | 12 QUICK RELEASE LATCHES | HUMIDITY INDICATOR 2 RELIEF VALVES | REUSABLE | NOT AVAIL. |
| |  | WARHEAD XM 135 | PICATINNY ARSENAL | M484 8810628 | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | 630 | NOT AVAIL. | ALUM. | CYL. | TOP | 8 ELASTOMERIC SHEAR MOUNTS | NOT AVAIL. | NONE | SEALED DEGREE OF PRESSURIZATION NOT AVAILABLE | DESICCANT | NOT AVAIL. | NOT AVAIL. | REINFORCING RIBS PROVIDE FLAT BASE ON COVER FOR STACKING | 4 STEEL STRAPS | TRANSVERSE FORK CHANNELS ON BOTTOM | 4 LONGITUDINAL WOOD SKIDS | 4 PINS ON BASE | RUBBER GASKET IN BASE | 28 WING TYPE CLAMPS | HUMIDITY INDICATOR | REUSABLE | NOT AVAIL. |
| |  | WARHEAD XM 135E1 | PICATINNY ARSENAL | M484E1 8827604 | 102.9 | 37.2 | 38.9 | 655 | NOT AVAIL. | STEEL | OVAL | TOP | ELASTOMERIC MOUNTS | NOT AVAIL. | NONE | | DESICCANT | NOT AVAIL. | NOT AVAIL. | 4 STACKING PADS ON COVER | NOT AVAIL. | 2 LIFTING EYES ON COVER. TOW EYES ON BASE | 4 LONGITUDINAL WOOD SKIDS | 2 PINS, ONE ON EACH END AT ℄ | RUBBER GASKET IN BASE | 30 WING TYPE CLAMPS | HUMIDITY INDICATOR RELIEF VALVES | REUSABLE | NOT AVAIL. |

N/A = NOT APPLICABLE

(LACROSSE cont'd on next page)

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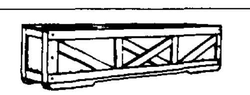
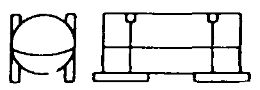
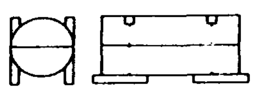
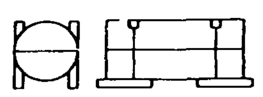
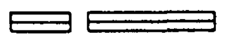
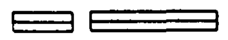
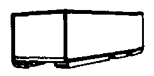
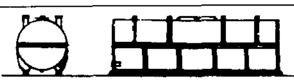
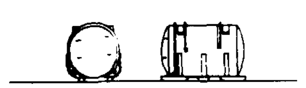
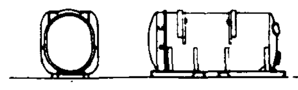
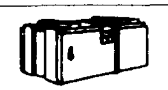
## TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. | | | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LENGTH | WIDTH | HEIGHT | | | | | | | | | | | | | | | | | | | | | | |
| LACROSSE (CONTINUED) | NOT AVAIL. | ROCKET MOTOR XM 10E1 8903373 | NOT AVAIL. | 9134600 | 114 | 36-5/8 | 43-3/4 | 996 | EMPTY ℄ | WOOD | RECT. | TOP AND SIDES ARE REMOVED AS A UNIT | NOT AVAIL. | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | NOT AVAIL. | NONE | NONE | NONE | 4 LONGITUDINAL WOOD SKIDS | ALIGNED BY BOLTS USED FOR FASTENING TOP TO BASE | NONE | 14 BOLTS SECURE TOP TO BASE ASSEMBLY | NONE | REUSABLE WORLDWIDE | — |
| |  | ROCKET MOTOR XM 10E1 8903373 | NOT AVAIL. | 8907300 | 117 | 26 | 29-3/4 | 400 | EMPTY ℄ | WOOD | RECT. | TOP AND SIDES ARE REMOVED AS A UNIT | NOT AVAIL. | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | STACK 4 HIGH | NONE | NONE | NONE | 4 LONGITUDINAL WOOD SKIDS | ALIGNED BY BOLTS USED FOR FASTENING TOP TO BASE | NONE | BOLTS SECURE TOP TO BASE ASSEMBLY | NONE | CONUS ONLY | — |
| LANCE |  | M5 MISSILE MAIN ASSEMBLAGE | CHAMPION COMPANY | M599 10161905 | 161 | 39 | 43 | 1705 | NOT AVAIL. | STEEL | CYL. | TOP | 10 RESILIENT MOUNTS | 50 G's IN ALL DIRECTIONS | NONE | 0.5 PSI | NONE | -65° TO +155°F | STACK 2 HIGH IN SHIPPING. 3 HIGH IN STORAGE | 8 BRACKETS ON COVER | 1-1/2-IN. BOLT THRU EACH SKID | 4 LIFT BARS ON BASE 6 LIFT HANDLES ON COVER 4 TIE-DOWN RINGS ON BASE FORKLIFT OPENINGS | 4 LONGITUDINAL WOODEN SKIDS | 6 PINS ON BASE | GASKET | 30 'T' BOLTS | NONE | REUSABLE WORLDWIDE | 10 |
| |  | M234 WARHEAD | CHAMPION COMPANY | M511 9219390 | 116 | 35 | 38 | 1000 | NOT AVAIL. | STEEL | CYL. | TOP | 4 RESILIENT MOUNTS | 20 G's IN ALL DIRECTIONS | NONE | 3 PSI | DESICCANT | -65°F TO +160°F | STACK 3 HIGH | 4 BRACKETS ON COVER | 1-1/2-IN. BOLT THRU EACH SKID | 4 LIFT BARS ON BASE 4 HOLES IN COVER 4 TOWING HOLES IN BASE | 4 LONGITUDINAL WOODEN SKIDS | 2 PINS ON BASE | GASKETS AND SHIELDING GASKETS | 22 'T' BOLTS | PAL CONNECTOR | REUSABLE WORLDWIDE | 10 |
| |  | M251 WARHEAD | CONTAINER RESEARCH CORP | M544 9211120 | 116 | 35 | 37 | 1000 | NOT AVAIL. | STEEL | CYL. | TOP | 4 RESILIENT MOUNTS | 30 G's IN ALL DIRECTIONS | NONE | NONE | NONE | STORAGE: -40°F TO +160°F | STACK 5 HIGH | 4 BRACKETS ON COVER | 1-1/2-IN. BOLT THRU EACH SKID | 4 LIFT BARS ON BASE 4 HOLES IN COVER 4 TOW TIE-DOWN RINGS ON BASE | 4 LONGITUDINAL WOODEN SKIDS | 6 PINS ON BASE | NONE | 20 'T' BOLTS | NONE | REUSABLE WORLDWIDE | 10 |
| |  | M29 FINS | ZERO MFG. CO. AND AC INCORPORATED | 10245730 | 56 | 28 | 6 | 59 | N/A | ALUM. | RECT. | TOP | POLYETHYLENE FOAM PADS | | NONE | 2.4 PSI | NONE | -65°F TO +160°F | N/A | 8 TOP 16 BOTTOM DIMPLED AREAS | NONE | 4 HANDLES | | PAINT MARKS | GASKET | 8 1/4-TURN LATCHES | NONE | REUSABLE WORLDWIDE | N/A |
| |  | M30 FINS | ZERO MFG. CO. AND AC INCORPORATED | 10245740 | 68 | 28 | 6 | 73 | N/A | ALUM. | RECT. | TOP | POLYETHYLENE FOAM PADS | | NONE | 2.4 PSI | NONE | -65°F TO +160°F | N/A | 8 TOP 16 BOTTOM DIMPLED AREAS | NONE | 4 HANDLES | | PAINT MARKS | GASKET | 10 1/4-TURN LATCHES | NONE | REUSABLE WORLDWIDE | N/A |
| HONEST JOHN |  | WARHEAD | PICATINNY ARSENAL | M473A1 8824908 | 146 | 45-1/2 | 53-3/8 | 1780 | LOADED: 48 FROM AFT END | LUMBER SHEATHED | RECT. | TOP, SIDES, & ENDS ARE REMOVABLE | 4 ELASTOMERIC SHEAR MOUNTS, 4 RUBBER FRICTION DAMPERS | (C) | NONE | NONE | NONE | NO LIMITS | (C) | NONE | NONE | TOW BARS ON ENDS | 6 LONGITUDINAL SKIDS | COVER AND SIDES ALIGNED BY LATCHES | NONE | 30 BOLT ACTUATED HOOKS | NONE | DISPOSABLE OCCASIONALLY REUSED. WORLDWIDE | — |
| |  | ROCKET MOTOR 762 mm M3 SERIES | DESIGNED BY DOUGLAS AIRCRAFT | 10048370 | 239-1/2 | 38-7/8 | 49 | 2430 | NOT AVAIL. | LUMBER SHEATHED | RECT. | TOP, SIDES, & ENDS ARE REMOVABLE | RUBBER LINED WOOD SADDLES | NONE | NONE | NONE | NONE, VENTILATED HAS DRAIN HOLES | SHIPPING AND STORAGE LIMITS: 0°F TO 120°F | STACK 2 HIGH | NONE | NONE | TOW BAR SLOTS FOR FORKS IN SKIDS LIFT EYES ON COVER | WOOD SKIDS ALONG EACH SIDE 190 IN.× 6 IN. BRG AREA APPROX 1040 IN.²/SKID. | COVER AND SIDES ALIGNED BY LATCHES | NONE | BOLT ACTUATED HOOKS | NONE | DISPOSABLE OCCASIONALLY REUSED. WORLDWIDE | — |
| PERSHING |  | WARHEAD XM137 | PICATINNY ARSENAL | XM 483 10623212 | 168 | 52-1/2 | 53 | 1800 | NOT AVAIL. | STEEL | CYL. | TOP | ELASTOMERIC SHEAR MOUNTS | NOT AVAIL | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | 4 STACKING PADS ON BODY | NOT AVAIL. | NOT AVAIL. | 4 LONGITUDINAL WOOD SKIDS | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | REUSABLE | NOT AVAIL. |
| |  | GUIDANCE & CONTROL XM 474 | SPACE CORP (DALLAS) | R-L0559A2 10625225-9 BASE ASS'Y F11025543 | 90 | 65 | 72 | 1947 | LOADED: 28 FROM HEAD FL, 26 FROM GROUND | STEEL | OVAL | END | 4 SHEAR MOUNTS 4 HYDRAULIC SHOCK ABSORBERS | NOT AVAIL. | ELECTRIC WRAP. END NOT HEATED. ELECT. SOURCE REQUIRED. | UNPRESSURIZED SEALED CONTAINER WITH RELIEF VALVE TESTED AT 5 PSIG | 176 UNITS OF DESICCANT CHANGED WHEN RH REACHES 30% | NOT AVAIL. | STACK 2 HIGH | 4 STACKING PADS ON BODY STRUCTURAL MEMBER | NONE | 4 TOW RINGS 8 ANCHOR SHACKLES 4 SLING SHACKLES FOR LIFTING 4 HANDLES ON COVER | 4 WOODEN SKIDS 22.5 IN.× 3-5/8 IN. BRG. AREA APPROX 81.5 IN.²/SKID | 2 PINS ON CONTAINER CLOSURE FLANGE | RUBBER O-RING | 4 'T' BOLTS & 20 CAM BOLTS | HUMIDITY TEMPERATURE & SHOCK INDICATORS ELECTRICAL CHECKOUTS G & C SECTION CONTAINS HIGH PRESSURE AIR LINE | REUSABLE | NOT AVAIL. |
| |  | 2ND STAGE XM 476 | SPACE CORP (DALLAS) | R-L056081 0625227-9 BASE ASS'Y F10607070 | 144-1/2 | 65 | 70 | 3745 | EMPTY: 64-7/8 FROM OPEN END. LOADED: 60 FROM OPEN END, 27 FROM GROUND | STEEL | OVAL | END | 16 SHEAR MOUNTS LOAD J7784-36 12 GABRIEL HYD. SHOCK ABSORBERS SP-330-K | NOT AVAIL. | CAN MAINTAIN TEMP BETWEEN 20°F-50°F WITH EXTERNAL TEMP AT -65°F STRIP TYPE | SAME AS ABOVE | 256 UNITS OF DESICCANT. CHANGED WHEN RH REACHES 30% | NOT AVAIL. | STACK 2 HIGH | SAME AS ABOVE | NONE | FORKLIFT CHANNELS (TRANSVERSE) ROLL-OVER RINGS | 4 WOODEN SKIDS. TWO: 61 IN.× 3-5/8 IN. BRG AREA APPROX 208 IN.²/SKID. | SAME AS ABOVE | RUBBER O-RING | 4 'T' BOLTS & 20 CAM BOLTS | | REUSABLE | NOT AVAIL. |
| | SAME AS 2ND STAGE ABOVE | 1ST STAGE XM 475 | SPACE CORP (DALLAS) | R-L0559A2 L0625225-9 BASE ASS'Y F11025543 | 144-1/2 | 65 | 70 | 3793 | EMPTY: 66.5 FROM OPEN END. LOADED: 61 FROM OPEN END, 27 FROM GROUND. | STEEL | OVAL | END | 16 SHEAR MOUNTS LORD J-7784-36 16 GABRIEL HYD. SHOCK ABSORBERS SP-330-R | NOT AVAIL. | HEATER ELECTRIC SOURCE IS REQUIRED 1ST & 2ND STAGES ARE IDENTICAL. | SAME AS ABOVE | 256 UNITS OF DESICCANT. CHANGED WHEN RH REACHES 30% | NOT AVAIL. | STACK 2 HIGH | SAME AS ABOVE | NONE | SAME AS ABOVE | TWO: 41-7/8 IN.× 3-5/8 IN. BRG AREA APPROX 139 IN.²/SKID. 10635050 & 10635049 | SAME AS ABOVE | RUBBER O-RING | 4 'T' BOLTS & 20 CAM BOLTS | SAME AS ABOVE | REUSABLE | NOT AVAIL. |
| NIKE-AJAX (PHASED OUT) |  | NOSE WARHEAD M2 (T26E) (TWO PER CONTAINER) | NOT AVAIL. | 76-1-1550 | 15-1/4 | 7-7/8 | 10-1/32 | EMPTY: 26 GROSS: 38 | ℄ | WOOD | RECT. | HINGED COVER | PADDED WOOD CRADLES | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | STACK 9 HIGH | NONE | NONE | NONE | CONSTRUCTION OF BOX FORMS 2 LONGITUDINAL SKIDS | ALIGNED BY CONSTRUCTION OF BOX | NONE | HINGE & HASP TYPE LATCH 1 STEEL BAND | NONE | DISPOSABLE | — |
| |  | CENTER WARHEAD M3 (T37E3) | NOT AVAIL. | 7548248 | 28-3/16 | 13-7/16 | 16-13/32 | EMPTY: 39 GROSS: 215.8 | ℄ | WOOD | RECT. | REMOVABLE COVER | PADDED WOOD CRADLES | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | STACK 9 HIGH | NONE | NONE | NONE | CONSTRUCTION OF BOX FORMS 2 TRANSVERSE SKIDS | ALIGNED BY CONSTRUCTION OF BOX | NONE | 4 HINGE & HASP TYPE LATCHES 2 STEEL BANDS | NONE | DISPOSABLE | — |
| | SAME AS CENTER WARHEAD ABOVE | REAR WARHEAD M4 (T38E3) | NOT AVAIL. | 7548249 | 26-5/8 | 12-3/4 | 16-3/32 | EMPTY: 32 GROSS: 153 | ℄ | WOOD | RECT. | REMOVABLE COVER | PADDED WOOD CRADLES | VERY LITTLE | NONE | NONE | NONE | NO LIMITS | STACK 9 HIGH | NONE | NONE | NONE | CONSTRUCTION OF BOX FORMS 2 TRANSVERSE SKIDS | ALIGNED BY CONSTRUCTION OF BOX | NONE | 4 HINGE & HASP TYPE LATCHES 2 STEEL BANDS | NONE | DISPOSABLE | — |

(C) = CLASSIFIED INFORMATION
N/A = NOT APPLICABLE

(NIKE-AJAX cont'd on next page)

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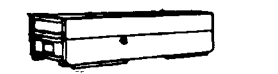
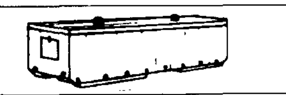
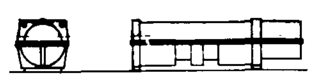
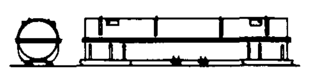
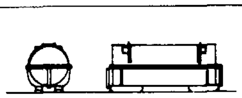
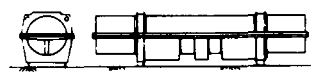
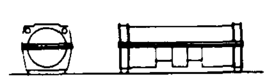
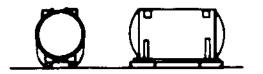
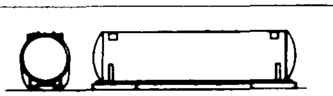
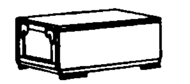
## TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. | | | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LENGTH | WIDTH | HEIGHT | | | | | | | | | | | | | | | | | | | | | | |
| NIKE-AJAX (cont'd) |  | ROCKET MOTOR M5 (THRUST STRUCT. M2) | NOT AVAIL. | M13A1 DRG. ORDDW NEC 46 | 174 | 27 | 28-1/2 | GROSS: 1949 | ℄ | WOOD | RECT. | TOP SPLIT AT ℄ | RUBBER LINED WOOD SADDLES (4) | VERY LITTLE | NONE | NONE | NONE | STORAGE: -10°F TO +130°F | STACK 4 HIGH | NONE | NONE | 2 COVER LIFTING RINGS | 4 LONGITUDINAL SKIDS | 4 WOOD POSTS, IN EACH CORNER 12 PINS | NONE | 4 LOCKING BOLTS 4 STEEL BANDS AROUND BODY | INSPECTION DOOR, ONE END | REUSABLE | NOT AVAIL. |
| |  | BODY M2 (XM 2E1) 8164450 | NOT AVAIL. | M326 8051738 | 263-1/2 | 38-5/32 | 41 | 2045 | ℄ | STEEL | CYL. | END (BOTH) | 4 SHOCK ABSORBERS 8051738E 8 ELASTOMERIC SHOCK MOUNTS 8051738H | 10 G's LONG. 13 G's LAT. 15 G's VERT. | NONE | 5 PSIG TESTED AT 20 PSIG VALVE OPENS 7 TO 10 PSIG | DESICCANT (148 UNITS) | NOT AVAIL. | STACK 3 HIGH | 8 SMALL STACKING PADS ON ANGLE RING | 4 STRAPS CONNECT END STACKING PAD TO FRAME | 2 LIFT EYES ON TOP OF BODY. 2 HAND GRIPS ON COVERS ROLL-OVER RINGS | 8 WOOD SKIDS SPACED EVENLY, LONGITUDINALLY FOUR: 36 IN.×3-5/8 IN. TWO: 30-9/16 IN. ×3-5/8 IN. TWO: 42-15/16 IN.×3-5/8 IN. TOTAL BRG AREA APPROX 940 IN.²/ SKID | 1 PIN IN 7 O'CLOCK POSITION ON BODY OF CONTAINER (EACH END) | SYNTHETIC RUBBER GASKET (EACH END) 8051738B | 8 BOLTS EACH END | HUMIDITY INDICATOR | REUSABLE | NOT AVAIL. |
| |  | ROCKET MOTOR M5 (THRUST STRUCT. M2) | NOT AVAIL. | M13 8026310 | 175 | 24-3/4 | 26-1/2 | EMPTY: 675 GROSS: 1883 | ℄ | WOOD | RECT. | TOP, SIDES, & ENDS REMOVED AS A UNIT | WOODEN CRADLES | VERY LITTLE | NONE | NONE | NONE | STORAGE: -10°F TO +130°F | STACK 4 HIGH | NONE | NONE | 2 COVER LIFTING RINGS | 4 LONGITUDINAL WOODEN SKIDS | NONE | NONE | 22 LAG BOLTS, IN BASE 4 STEEL BANDS AROUND BODY | NONE | REUSABLE | NOT AVAIL. |
| SERGEANT (PHASED OUT) |  | WARHEAD XM 38 | PICATINNY ARSENAL | XM 421 9125576 | 104-1/2 | 48 | 48-1/2 | 819 | NOT AVAIL. | ALUM. | OVAL | TOP HINGED | POLYURETHANE FOAM SKIDS | 20 G's SHOCK 10 G's VIB. ACCEL. | NOT AVAIL. | 4.5 ±0.5 PSI CAN STAND 9.5 ±0.5 PSI | DESICCANT | SHIPPING AND STORAGE: -80°F TO +185°F | NOT AVAIL. | 4 STACKING PADS ON BODY STRUCTURAL MEMBER | NOT AVAIL. | FORK OPENINGS SIDES & ENDS 4 LIFT PTS. ON STACKING PADS. TOW HOLES. | LONGITUDINAL WOOD SKIDS | 4 PINS ON CONTAINER BODY | NOT AVAIL. | 12 CAM BOLTS 8 LOCKING STUDS | ELECTRICAL FITTINGS HUMIDITY INDICATOR | REUSABLE | NOT AVAIL. |
| |  | ROCKET MOTOR XM 53 | DESIGNER: APPLIED DESIGN | XM 486 10397884 (APPLIED DESIGN NO. 594A1) | 220-1/8 | 47-1/8 | 48-1/8 | 1710 | NOT AVAIL. | STEEL | CYL. | TOP 8 HINGES | ELASTOMERIC MOUNTS | 20 G's VERT. & LATERAL 30 G's LONG. | 5 ORG HEATERS MESH TYPE +10° ±5°F, WITH OUTSIDE TEMP -65°F POLYURETHANE INSULATION | +3 PSIG ±0.5 -1 PSIG ±0.5 A.P.R.V. | DESICCANT | OPERATION: -65°F TO +125°F STORAGE: -80°F TO +155°F | TWICE ITS GROSS WEIGHT | 4 STACKING PADS ON BODY SHELL 2 HIGH | STEEL STRAPS | 8 TIE-DOWN AND LIFTING EYES ON STRUCTURAL MEMBERS BELOW ℄ | 4 LONGITUDINAL WOOD SKIDS | 4 PINS | RUBBER O-RING SEAL | 36 'T' BOLTS | HIGH & LOW TEMP INDICATOR HUMIDITY INDICATOR | REUSABLE | NOT AVAIL. |
| |  | GUIDANCE & CONTROL AN/DJW-8 | DESIGNER: APPLIED DESIGN | XM487 10397534 (APPLIED DESIGN NO. 593A1) | 107-1/4 | 47-1/8 | 47-3/8 | 810 | ℄ | STEEL | CYL. | TOP 6 HINGES | ELASTOMERIC MOUNTS (APPLIED DESIGN 593A236) | 25 G's IN THREE AXES | 3 MESH TYPE HEATERS -20° ±0.5F, WITH TEMP -65°F OUTSIDE | +3 PSIG ±0.5 -1 PSIG ±0.5 TESTED AT 4.5±0.5 PSI | DESICCANT | OPERATION: -65°F TO +125°F STORAGE: -80°F TO +155°F | 3960 LB. 10 LB/FT² SNOW LOAD | 4 STACKING PADS ON BODY SHELL | 4 STEEL STRAPS | 4 LIFT HOLES IN TOP OF FRAME — 4 TOW EYES. BODY NOTCHED FOR FORKS. | 4 LONGITUDINAL WOOD SKIDS | 4 PINS | RUBBER O-RING SEAL | 20 'T' BOLTS | ELECTRICAL HIGH & LOW TEMP INDIC HUMIDITY INDICATOR | REUSABLE | NOT AVAIL. |
| |  | ROCKET MOTOR XM 53 | DESIGN: JET PROPULSION LAB PRIME: SPERRY UTAH | XM 419 11065436 | 222 | 48 | 49 | 1240 | AT ℄ | ALUM. | CYL. | HINGED TOP COUNTER-BALANCED BY TORSION BARS | PACKED IN RIGID POLYURETHANE FOAM. SHOCK MITIGATION FROM POLYURETHANE FOAM SKIDS | 20 G's TRANSVERSE. 30 G's LONGITUDINAL | ELECTRIC BLANKET TEMPERATURE KEPT NOT LESS THAN 20°F WITH OUTSIDE TEMP AT -65°F | BREATHER VALVES OPERATE AT -0.5 OR +2.5 PSIG. | NO DESICCANT IN CONTAINER. SILICA GEL DESICCANT SEALED IN ROCKET MOTOR | STORAGE LIMITS: -40°F TO +130°F | STACK 2 HIGH | SMALL NOTCHES ON SKIDS FRAME SURROUNDS CONTAINER (NOT SHIPPED STACKED) | SMALL RODS CONNECTING STACKING PAD TO FRAME (4 RODS) | 4 LIFT HOLES IN TOP OF FRAME. 4 TOW EYES. BODY NOTCHED FOR FORKS. | 2 TRANSVERSE CRUSHABLE THIN-WALLED STEEL SKIDS FILLED WITH POLYURETHANE FOAM | 8 PINS (FRONT EDGE) | SILICONE GASKET | SCREW ACTUATED HOOKS | HUMIDITY & TEMPERATURE INDICATORS ELECTRICAL CHECKOUTS | REUSABLE | 10 |
| |  | GUIDANCE & CONTROL AN/DJW-8 | DESIGN: JET PROPULSION LAB PRIME: SPERRY UTAH | XM 420 11065435 | 123 | 48 | 49 | 827 | ℄ | ALUM. | CYL. | HINGED TOP COUNTER-BALANCED BY TORSION BARS | MOUNTED RIGIDLY IN CONTAINER. SHOCK MITI-GATION FROM POLYURETHANE FOAM SKIDS. | 25 G's IN 12 ms ALL DIRECTIONS | SPACE HEATER PROVIDES TEMPERATURE CONTROL | BREATHER VALVES OPERATE AT -0.5 OR +2.5 PSIG. | SILICA GEL DESICCANT, 30-40% MAXIMUM RELATIVE HUMIDITY | STORAGE LIMITS: -80°F TO +160°F | SAME AS ABOVE | SAME AS ABOVE | SAME AS ABOVE | SAME AS ABOVE | SAME AS ABOVE | 4 PINS (FRONT EDGE) | SILICONE GASKET | SAME AS ABOVE | HUMIDITY & TEMPERATURE INDICATORS ELECTRICAL CHECKOUTS | REUSABLE | 10 |
| NIKE-HERCULES |  | WARHEAD HE | DESIGNED BY DOUGLAS MFG: FARM TOOL & SUPPLY DENVER | XM 409 9031006 | 99-1/4 | 54-3/8 | 61-1/2 | EMPTY: 1925 GROSS: 3170 | ℄ | STEEL | CYL. | END (ONE) | 8 COMPRESSION SPRINGS AND 8 HYDRAULIC SHOCK ABSORBERS | NOT AVAIL. | NONE | 5 PSIG | DESICCANT 30% RH | -65°F TO +165°F | NOT AVAIL. | 4 STACKING PADS ON BODY | 4 SMALL STRAPS CONNECT STACKING PAD TO FRAME. SKIDS NOTCHED | SLING ON TOP OF BODY, 4 TOW RINGS ON FRAME. 2 HAND GRIPS ON COVER. | 4 WOODEN SKIDS 26.5 IN.× 6 IN. BRG AREA APPROX 16.5 IN.× 6 IN. = 99 IN.²/ SKID | 2 PINS ON BODY NEAR TOP | SILICONE RUBBER SEAL MIL-R-5847 | 12 QUICK OPENING LATCHES | HUMIDITY INDICATOR | REUSABLE DESIGNED FOR ALL FORMS OF HANDLING, TRANS., & STORAGE | 10 |
| | NOT AVAIL. | WARHEAD M17 (T-45) FXP 88467 | NOT AVAIL. | FXP 90955 | 34-15/16 | 34-15/16 | 39-1/4 | GROSS: 1250 | ℄ | WOOD | RECT. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NONE | NONE | NONE | NO LIMITS | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | NONE | NOT AVAIL. | NONE | DISPOSABLE | — |
| |  | BODY SECTION | DESIGNED BY DOUGLAS MFG: DUBIE CLARK | M410 9031007 | 223-1/2 | 54-3/4 | 61-1/2 | EMPTY: 3375 GROSS: 4561 | NOT AVAIL. | STEEL | CYL. | END (ONE) | 8 COMPRESSION SPRINGS AND 8 HYDRAULIC SHOCK ABSORBERS | NOT AVAIL. | NONE | 5 PSIG | DESICCANT 30% RH | -65°F TO +165°F | NOT AVAIL. | 4 STACKING PADS ON BODY | 4 SMALL STRAPS CONNECT STACKING PAD TO FRAME. SKIDS NOTCHED | SLING ON TOP OF BODY, 4 TOW RINGS ON FRAME. 2 HAND GRIPS ON COVER | 4 WOODEN SKIDS 54-1/8 IN. ×6 IN. BRG AREA APPROX 44-1/8 IN.×6 IN. = 265 IN.²/SKID | 2 PINS ON BODY NEAR TOP | SILICONE RUBBER SEAL MIL-R-5847 | 12 QUICK OPENING LATCHES | HUMIDITY INDICATOR | REUSABLE DESIGNED FOR ALL FORMS OF HANDLING, TRANS., & STORAGE | 10 |
| | SEE M13 & M13A1 ABOVE | ROCKET MOTOR M5E1 OR M88 (W/IGNITER) | — | USES CONTAINERS M13A1 OR M13 (SEE ABOVE) | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| |  | ROCKET MOTOR M30 9031181 | NOT AVAIL. | 8034264 | 105-1/8 | 43-1/4 | 47-7/16 | GROSS: 3844 | ℄ | PLYWOOD SHEATHED | RECT. | AS A UNIT | 2 METAL CRADLES SUPPORTING MOTOR. CRADLES BOLTED TO WOODEN BASE. | NOT AVAIL. | NONE | NONE | NONE | NO LIMITS | NOT AVAIL. | NONE | NONE | LIFTING BRACKETS ON ENDS USED TO REMOVE COVER | 4 LONGITUDINAL STEEL SKIDS | NONE | NONE | COVER BOLTED TO BASE | NONE | REUSABLE IF SERVICEABLE | — |
| |  | ROCKET MOTOR M42 W/4 IGNITERS M24 | NOT AVAIL. | 9031177 | 180 | 43 | 54-1/4 | 1475 | NOT AVAIL. | PLYWOOD SHEATHED | RECT. | TOP AND SIDES ARE REMOVED AS A UNIT | 2 METAL CRADLES SUPPORTING ASS'Y ON RUBBER PADS. CRADLE BOLTED TO WOODEN BASE | UNKNOWN | NONE | NONE | NONE SCREENED VENTILATION OPENINGS EACH END | NO LIMITS | TWICE WEIGHT OF LOADED CONTAINER | NONE | NONE | 2 SLINGS ATTACHED TO BASE FOR HOISTING | 4 LONGITUDINAL WOOD SKIDS | COVER FITS OVER BASE | NONE | TOP & SIDES ATTACH TO BASE WITH 26 LAG SCREWS | INSPECTION DOOR EACH END | DESIGNED FOR ALL FORMS OF HANDLING, TRANS. AND STORAGE | 10 |

(cont'd on next page)

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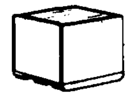
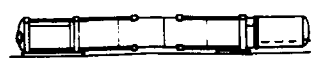
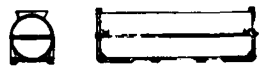
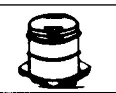
## TABLE 2-2 (cont'd)

| MISSILE OR ROCKET | PROFILE | COMPONENT PACKAGED | MFG. OF CONTAINER | CONTAINER DRAWING NUMBER | OUTSIDE DIMENSIONS, IN. LENGTH | OUTSIDE DIMENSIONS, IN. WIDTH | OUTSIDE DIMENSIONS, IN. HEIGHT | WEIGHT OF EMPTY CONTAINER, LB | CENTER OF GRAVITY, IN. | MATERIAL | SECTIONAL CONFIGURATION | METHOD OF OPENING | SUSPENSION SYSTEM | SHOCK PROTECTION TO COMPONENT | TEMPERATURE PROTECTION TO COMPONENT | PRESSURE PROTECTION TO COMPONENT | HUMIDITY PROTECTION TO COMPONENT | OPERATING TEMPERATURE RANGE OF CONTAINER | ALLOWABLE BEARING LOAD | STACKING DEVICES | UNITIZING DEVICES | HANDLING DEVICES | SUPPORTS | COVER ALIGNING DEVICES | SEALING DEVICES | LATCHING DEVICES | COMPONENT CHECKOUT DEVICES | DISPOSITION AND DISTRIBUTION | EXPECTED LIFE, YR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CORPORAL (PHASED OUT) |  | INERT WARHEAD XM 15 | PICATINNY ARSENAL | FXP 97901 | 34-13/16 | 34-13/16 | 45-3/4 | EMPTY: 260 GROSS: 1614 | ℄ | WOOD | RECT. | TOP AND SIDES REMOVED AS A UNIT | WOOD CRADLE | NONE | NONE | NONE | NONE | NO LIMITS | STACK 3 HIGH | NONE | NONE | NONE | 3 WOOD SKIDS | NONE | NONE ON CONTAINER | WOOD SCREWS | NONE | REUSABLE IF SERVICEABLE | — |
| |  | AFT BODY SECTION M4 | NOT AVAIL. | M351 8138851 | 461 | 49 | 58 | EMPTY: 6376 END BELL: 648 GROSS: 9107 | APPROX. AT ℄ | STEEL | CYL. | END BELL TYPE COVER | TORSION BARS (SEE CHAPTER FOR DETAILS) | NOT AVAIL. | NONE | 5 PSIG KEPT BETWEEN 3 & 7 PSIG | MAXIMUM 35% RH AT 70°F 800 UNITS OF DESICCANT (55 LB) | NOT AVAIL. | STACK 2 HIGH | NONE | NONE | HANDLING BEAM (M5) ATTACHED TO TORSION BAR HOUSINGS FOR LIFTING | 4 LONGITUDINAL WOODEN SKIDS | GUIDE PIN ON CONTAINER FLANGE | GASKET | 19 BOLTS | RELIEF VALVES & HUMIDITY INDICATOR ON EACH END. TWO ACESS COVERS ON FWD END | REUSABLE | NOT AVAIL. |
| |  | FORE BODY SECTION, N3 (COMPONENTS SHIPPED TELESCOPED) | NOT AVAIL. | 8189075 (NEW DESIGN-TABULATED) SIMILAR OLD DESIGN 8189046 | 68-3/4 | 40-3/4 | 37-5/16 | EMPTY: 282 GROSS: 407 | ℄ | PLYWOOD, CARDBOARD INNER PACK | RECT. | TOP, ENDS, AND SIDES REMOVABLE | NOT AVAIL. | UNKNOWN | NONE | NONE | BARRIER BAG. 176 UNITS OF DESICCANT USED. | NO LIMITS | RECOMMENDED STACKING 3 HIGH (CAN BE STACKED HIGHER) | NONE | NONE | NONE | 3 TRANSVERSE WOOD SKIDS | NONE | NONE ON CONTAINER, BARRIER MATERIAL AROUND ITEM | BOLTS AND STEEL STRAPS | HUMIDITY INDICATOR & INSPECTION PORT ON BARRIER BAG | REUSABLE IF SERVICEABLE | — |
| NIKE—ZEUS (PHASED OUT) |  | WARHEAD SECTION XM 482 9709601 | DOUGLAS | 5837589 MODEL NO. DM-1506-5A | 104 | 34-1/4 | 35-1/4 | 844 | NOT AVAIL. | STEEL (LOW CARBON) | CYL. | TOP HINGED | MOLDED RUBBERIZED HAIR PADS | 22 G's AXIALLY, 24 G's TRANSVERSE MIL-SPEC-P116C | NONE | NONE | SAME AS SUSTAINER CONTAINER | -65°F TO +160°F | STACK 3 HIGH | NOT AVAIL. | NOT AVAIL. | TRANSVERSE FORK OPENINGS | 4 LONGITUDINAL WOODEN SKIDS | ALIGNED BY HINGES | NONE | 2 SLIDING HINGE PIN LATCHES | NONE | REUSABLE | 5-10 EXPOSED |
| |  | GUIDANCE SECTION 9830729 | DOUGLAS | 9705611 | 94-1/2 | 45-1/2 | 49 | EMPTY: 900 GROSS: 1740 | NOT AVAIL. | STEEL | CYL. | TOP HINGED | RUBBERIZED HAIR PADS | NOT AVAIL. | NOT AVAIL. | NONE | NOT AVAIL. | -65°F TO +160°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | TRANSVERSE FORK OPENINGS HOISTING AND TIE-DOWN RINGS | 4 LONGITUDINAL WOODEN SKIDS | ALIGNED BY HINGES | NOT AVAIL. | 2 SLIDING HINGE PIN LATCHES | NOT AVAIL. | REUSABLE | 5-10 EXPOSED |
| |  | THIRD STAGE ROCKET MOTOR 9708979-2 | DOUGLAS | 9705612 MODEL NO. 1506-3 | 38 | 38 | 44 | EMPTY: 450 GROSS: 1200 | NOT AVAIL. | STEEL (LOW CARBON) | VERTICAL CYL. | HINGED COVER | RUBBERIZED HAIR PADS | 8 G's AXIALLY, 13 G's TRANSVERSE MIL-SPEC-P116C | NONE | NONE | SAME AS BELOW | -65°F TO +160°F | NOT AVAIL. | NOT AVAIL. | NOT AVAIL. | 2 SETS OF FORK OPENINGS AT 90 DEG. HOISTING RINGS | WOODEN SKIDS AROUND BASE | ALIGNED BY HINGES | NONE | 1 SLIDING HINGE PIN LATCH | NONE ON CONTAINER | REUSABLE | 5-10 EXPOSED |
| |  | SUSTAINER ROCKET MOTOR 9708888 | DOUGLAS | 9700776 MODEL NO. DM-1506-2 | 221-1/2 | 50-13/16 | 53 | EMPTY: 3112 GROSS: 11,219 | NOT AVAIL. | STEEL (LOW CARBON) | CYL. | TOP HINGED & COUNTER-BALANCED | RUBBERIZED HAIR PADS CELOTEX SPACERS | 19 G's AXIALLY, 13 G's TRANSVERSE MIL-SPEC-P116C | NONE | NONE | NO HUMIDITY PROTECTION PROVIDED BY CONTAINER. RH OF ITEM CONTROLLED TO A MAX. OF 41 GRAMS OF WATER/LB OF AIR BY SEALING ITEM IN MOIST-URE PROOF BAG WITH DESICCANT | -65°F TO +160°F | STACK 2 HIGH | STACKING LUGS PROVIDED | NOT AVAIL. | TRANSVERSE FORK OPENINGS HOISTING AND TIE-DOWN RINGS | 4 LONGITUDINAL WOODEN SKIDS | ALIGNED BY HINGES | NONE | 5 SLIDING HINGE PIN LATCHES | NONE ON CONTAINER | REUSABLE | 5-10 EXPOSED |
| | SAME AS SUSTAINER ABOVE | FIRST STAGE MOTOR | DOUGLAS | 9700777 MODEL NO. DM-1506-3 | 221-1/2 | 50-13/16 | 53 | EMPTY: 2464 GROSS: 14,150 | NOT AVAIL. | STEEL (LOW CARBON) | CYL. | TOP HINGED & COUNTER-BALANCED | RUBBERIZED HAIR PADS | 19 G's AXIALLY, 24 G's TRANSVERSE MIL-SPEC-P116C | NONE | NONE | | -65°F TO +160°F | STACK 2 HIGH | STACKING LUGS PROVIDED | NOT AVAIL. | TRANSVERSE FORK OPENINGS HOISTING AND TIE-DOWN RINGS | 4 LONGITUDINAL WOODEN SKIDS | ALIGNED BY HINGES | NONE | 5 SLIDING HINGE PIN LATCHES | NONE ON CONTAINER | REUSABLE | 5-10 EXPOSED |

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# CHAPTER 3
# SOURCES OF DAMAGE AND HAZARDS PECULIAR TO ARMY MISSILE AND ROCKET CONTAINERS

*Hazards to materiel and containers—resulting from natural and induced environments—are presented.*

## 3-1 GENERAL

Current Army policy—based on the need for worldwide deployment—dictates that all materiel, including containers, have characteristics capable of withstanding the rigors of a logistic pattern geared to worldwide distribution. Consequently, the container and its contents, in combination, must provide for all environments and modes of transportation in addition to the hazards peculiar to the handling of materiel in transit.

The environment in which a container must operate subjects it to hazards which may produce damage to both the container and its contents. To protect the integrity of the missile, current missile designs include built-in protection; however, the container must supplement these characteristics to provide for all of the hazards which may be encountered from the point of initial supply to the launch site. The "shoot and scoot" tactics currently employed by the Army in the field require a high degree of reliability; consequently, the protective level of the container cannot be compromised.

The hazards to which a container is exposed are many, subjecting it to conditions which may result in physical damage caused by the rigors of the logistic pattern and deterioration as the result of prolonged climatic exposure.

The logistic pattern starts at the initial point of supply, usually the manufacturing plant. Regardless of the proven adequacy of the engineered prototype, the performance of the manufactured product may prove deficient as the result of an ineffective quality assurance program. Poor housekeeping, inferior materials, substandard workmanship, and lack of effective quality control will result in a deficient container thus compounding the damaging effects of the hazards that the container will encounter. Unfortunately, these are beyond the control of the designer. Consequently it must be assumed that the finished procured product, as represented by the prototype, will meet the contractual requirements and that the container will prove adequate within the established limits of the proposed application.

## 3-2 SOURCES OF LOGISTIC HAZARDS

Logistic hazards result principally from manual and mechanized handling, in-plant and warehouse storage, movement in transit, and field depot storage. A description of the hazards follows.

### 3-2.1 MANUAL AND MECHANIZED HANDLING

Manual and mechanized handling of the loaded container at the manufacturing plant subject it and its contents to physical abuse. The most severe condition is that of impact shock. Damaging shock forces within this category are normally the result of:

a. Accidental dropping
b. Conveyor system unloading
c. Abrupt stops and starts of mechanical devices.

The anticipated height of drop, producing the most severe impact shock, is based on the potential hazards that may be encountered within this phase of the logistic pattern. By placing the container in its proper weight classification, an estimate of the severity of treatment it will receive can be made (see Table 3-1).

### 3-2.2 IN-PLANT AND WAREHOUSE STORAGE

In-plant and warehouse storage operations expose the container to additional hazards. Of particular concern is the practice of stacking as dictated by efficient warehouse utilization. This subjects the container to static loads peculiar to this limited phase of the overall delivery cycle. Consequently, the structure of the container often must be made capable of withstanding high static loading.

To conserve space and reduce costs in both shipping and storage, missile containers are usually stacked two or more tiers high, depending upon their size and weight. Usually, containers in excess of 2500 lb gross weight are limited to stacks of two high; those less than 2500 lb may be stacked three high (Fig. 3-1). Containers with gross weight in excess of 5000 lb are usually too large to stack.

Small rockets and missiles may be housed within

**TABLE 3-1**
**TYPICAL DROP HEIGHTS**

| Weight Range Gross Weight $W$, lb | Type of Handling | Drop Height, in. |
|---|---|---|
| $0<W\leq 20$ | 1 man throwing | 42 |
| $20<W\leq 50$ | 1 man throwing | 36 |
| $50<W\leq 250$ | 2 men carrying | 30 |
| $250<W\leq 500$ | light equipment handling | 24 |
| $500<W\leq 1000$ | light equipment handling | 18 |
| $W>1000$ | heavy equipment handling | 12 |

containers having a configuration and gross weight compatible to high stacking. Containers within this category may be considered to be subject to stacking 15 ft high as governed by the lift of the conventional forklift.

### 3-2.3 DURING TRANSIT

During transit to its ultimate destination, the container is subjected to rough handling, shock, and vibration. The delivery of Army containers is accomplished by an assortment of transport vehicles and more often combinations of these conveyances (railroad, truck, aircraft, marine vessel). Hazards associated with each of the modes of transportation are discussed.

#### 3-2.3.1 Railroad Shipments

Railroad shipments (Figs. 3-2 and 3-3) subject the container to high impact shocks as the result of humping during switching operations. It is generally believed that railroad switching operations in classification yards cause the most severe damage to lading imposed during rail shipment. Consequently, the analysis of rail shipments shall be concerned primarily with the imposed shock as the result of humping.

Shock data recorded during flat car rail impact tests have been plotted and are depicted in Fig. 3-4. These data may be applied to shock investigations relating to conventional lading of nonexplosive materiel. The test data indicate that the imposed shock is greatest in the longitudinal plane and is most prevalent at speeds of from 8-10 mph. The most severe conditions occur during flat car shipment, a conveyance most applicable to military transit requirements. Based on the recorded data and the prevalent transit parameters, the following design criteria can be applied and will encompass the majority of impact conditions experienced within the military rail environment:

a. Rail flat car: nonexplosive lading

b. Impact speed: 10 mph

c. $G$ force imposed on lading in longitudinal plane: 10 $g$'s

d. Pulse duration: 30 ms.

In addition to shock, there are critical train speeds at which the rail joint impulses become resonant with the natural frequencies of the car on its vertical suspension. These disturbances are the result of track and wheel irregularities and occur chiefly at rail joints, frogs, and crossings. From many tests conducted by both military and civilian agencies, forcing frequencies developed by a freight car moving at speeds ranging from 20 to 91 mph are 2 to 7 Hz. The $G$ forces imposed upon the lading by the steady-state vibration of the rail car are of appreciably less magnitude (0.5 $g$) than those generated by impact. The design of the container suspension system shall be based on the shock impact requirements and will encompass those relatively smaller forces produced by the prevalent vibrations. The suspension system must, however, be designed to provide a natural frequency in excess of 10 Hz to avoid the critical range of 2-7 Hz peculiar to rail transport. (See par. 1-14, "Resonance".)

#### 3-2.3.2 Truck Shipments

The forces imposed by truck shipment (Fig. 3-5) are so varied that it becomes difficult to isolate the area most prevalent for design consideration. The destructive forces prevalent in truck shipments are the result of impact shock, fatigue, and vibration. A discussion of each of these destructive forces follows:

a. *Impact Shock:* Impact shock imposed upon vehic-

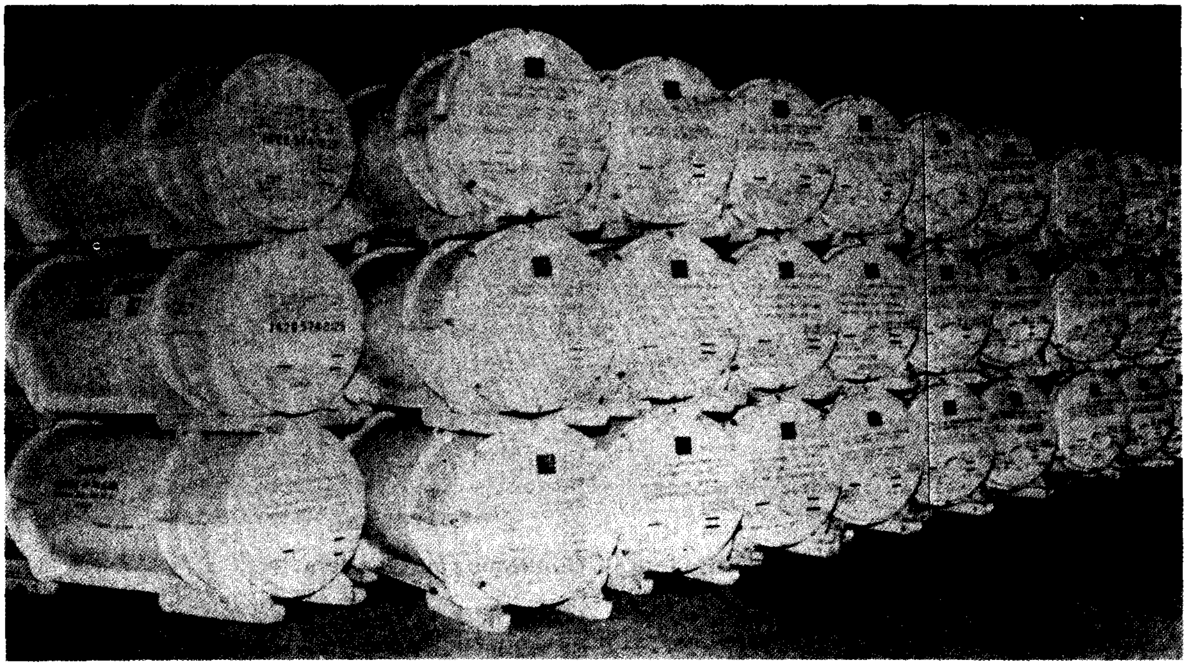


Figure 3-1. Stacking of Containers in Storage Warehouse

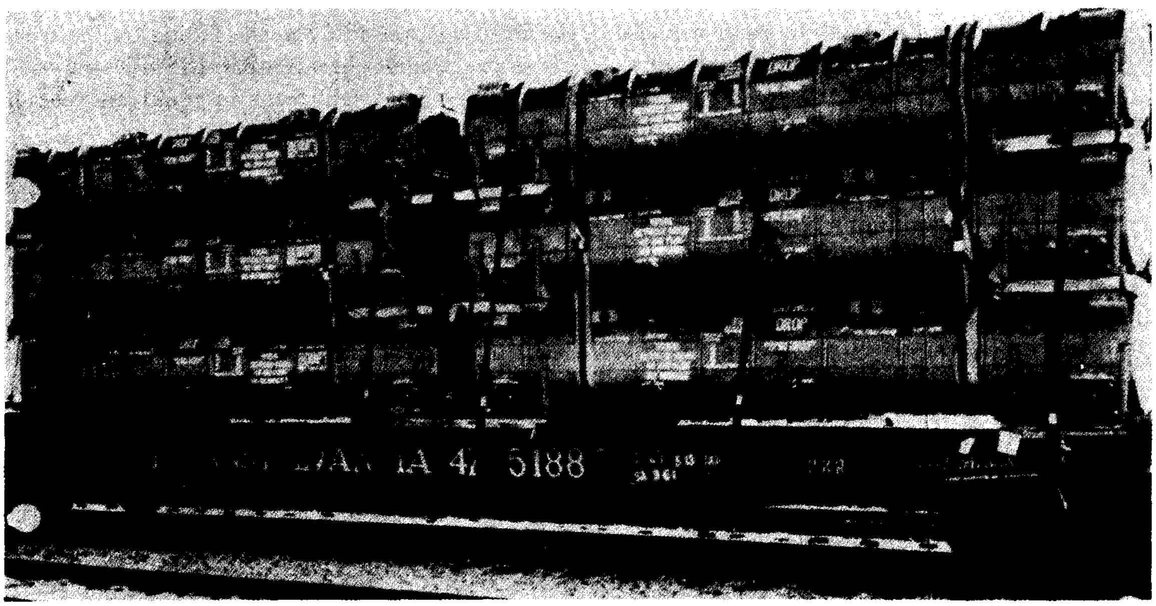


Figure 3-2. Shipment of Containers on Flat Car

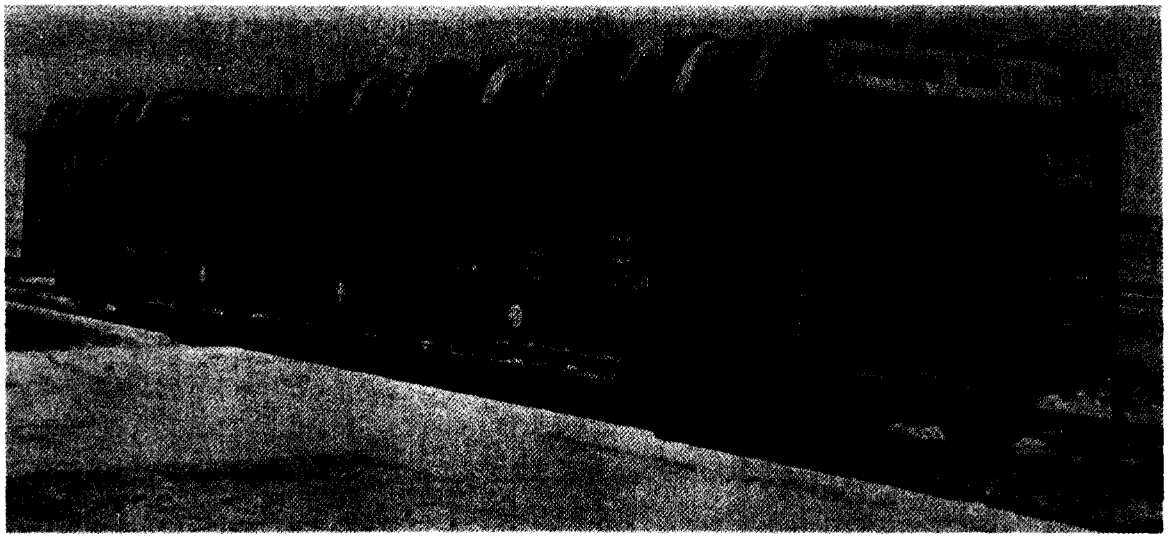


**Figure 3-3. Shipment of Containers in Gondola**

ular lading is often the result of a sudden change in motion. Sudden braking of the vehicle and irregularities of the road surface (potholes, etc.) impart to the lading a single transient shock wave, and any resulting failure is instantaneous. Damage-producing shock input usually is applied to the vertical axis of the lading and is most often the result of a bump in the road.

The Munson Road Test, adopted by the Army to evaluate the performance of over-the-road vehicles, introduces all of the mechanical disturbances prevalent in the transit environment of worldwide distribution. The accelerations measured at the cargo bed of a typical vehicle have been tabulated and are included in Fig. 3-6. These reactions of the truck bed are typical of the forces imposed upon lading transported by truck. As previously stated, these forces vary and their values fluctuate; however, it may be assumed that only those applied vertically are significant and the magnitude of the average shock is equal to 3 *g*'s.

Due to the nature of the test bed, the applied force can be considered repetitive and to have a spectrum comparable to that of a half-sine wave. The amplitude of the sinusoidol shock wave generated by the vehicle bed can be considered equal to the vertical displacement of the truck bed. The displacement amplitude of the spring-suspended cargo deck can be conveniently measured and may be as great as 4 in. These data can be applied to illustrate graphically the nature of the induced shock; however, the frequency, being a function of vehicular speed and the irregularities of the road bed, becomes difficult to isolate.

To facilitate laboratory simulation of the effects of the over-the-road environment, Fig. 3-7 equates the developed data (imposed *G*'s and amplitude) into equivalent free-fall drop heights.

A typical condition prevalent in the environment of worldwide distribution subjects the lading to repetitive shock inputs of 3 *g*'s with a vertical cargo deck displacement of 3 in. Although the actual movement of the unlashed cargo is 3 in., the accumulative force of impact imposed upon the lading by the truck bed is several degrees greater than the force imposed by a single free-fall height from an equal distance upon a static impact surface.

Fig. 3-7 shows that the magnitude of the imposed force under the conditions described is comparable to that generated if the lading were subject to a free-fall drop of 18 in. Impacting upon the metal deck of a transport vehicle, the lading would be subject to a force of 101 *g*'s assuming a shock-rise time of 3 ms (see Tables 1-2 and 1-3).

The laboratory simulation actually imposes a shock input substantially greater than that experienced by the lading; however, the cumulative effects of the repetitive disturbances of transit produce progressive abuse which in time results in failure comparable to that produced by the free-fall test.

b. *Fatigue Failure:* Fatigue failure is prevalent in the environment of vehicular transit and occurs when unlashed lading is thrown into the air each time its upward acceleration exceeds the acceleration of gravity. The lading then falls freely upon the vehicle and its downward velocity is arrested suddenly. The height to which the lading is thrown is usually rela-

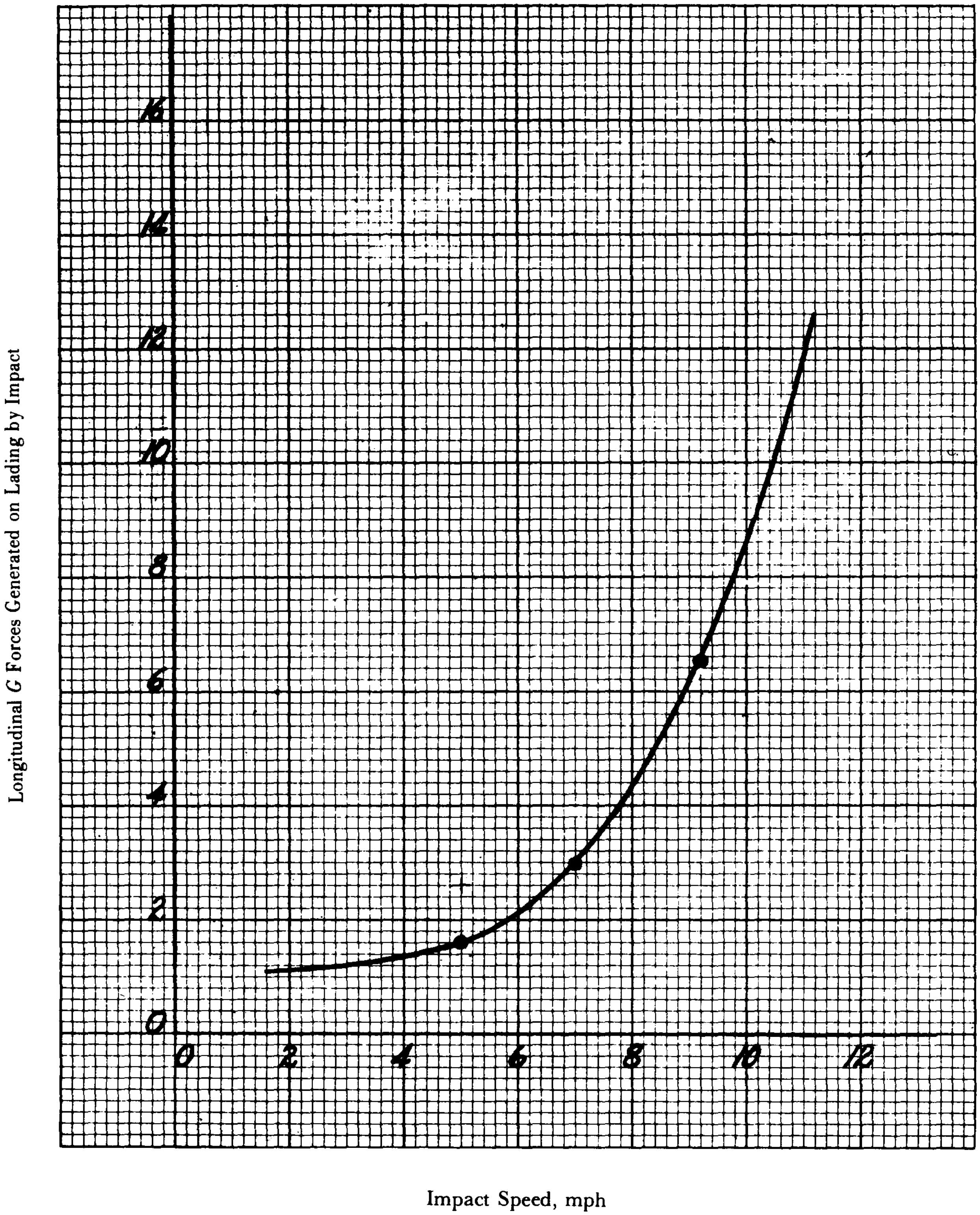



**Figure 3-4. Longitudinal *G* vs Impact Speed of Rail Car Humping**

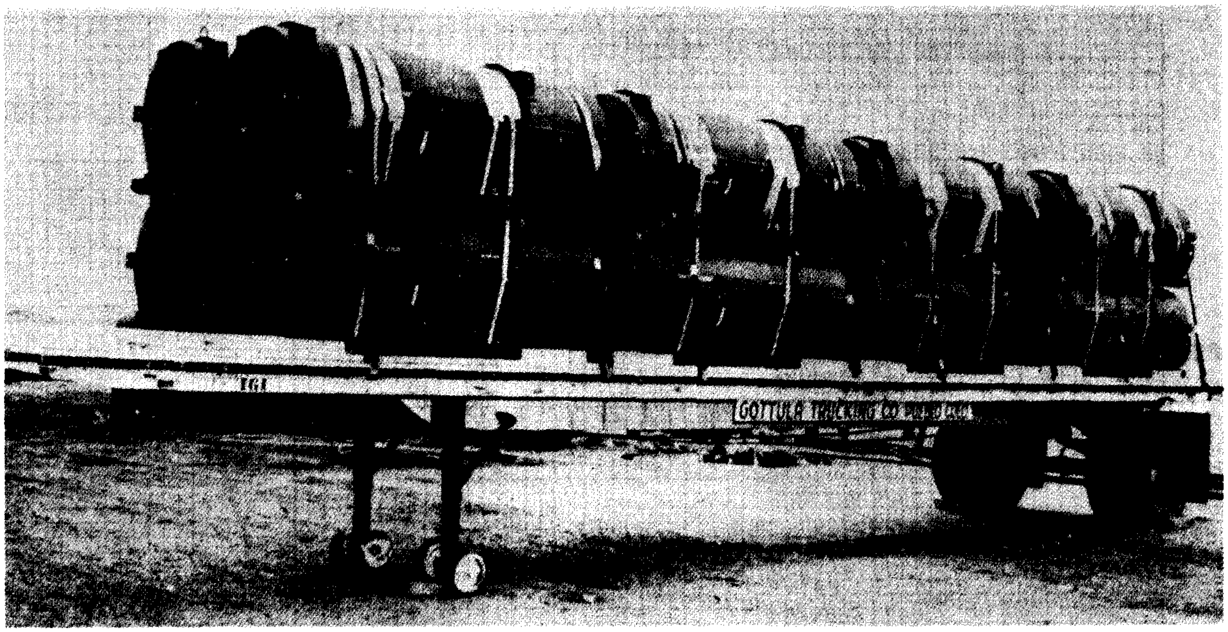


**Figure 3-5. Shipment of Containers on Truck Trailer**

tively small and the force of impact of insignificant magnitude; however, the many repetitions that occur in a long trip introduce accumulative impact and result in fatigue failure of the lading and/or its components.

As previously discussed, the designer can provide for this phenomena by equating the factors producing fatigue to a comparable drop test to produce conveniently the same effect upon the lading as that experienced in the transit environment.

c. *Vibrations:* Vibrations are introduced when the vehicle hits frequent successive road irregularities producing oscillatory disturbances. Uniformly spaced irregularities producing repetitive disturbances are significant since the frequency of their application may introduce resonance. Disturbing frequencies prevalent in a truck transit environment are found within the 2- to 7-Hz range. Since the natural frequency of Army vehicles may occasionally be as great as 20 Hz, a minimum natural frequency of the suspension system of 25 Hz is recommended to avoid the occurrence of a resonant condition.

### 3-2.3.3 Aircraft Movement and Aerial Delivery

This category of transport media encompasses:

a. Air transport (cargo aircraft)

b. Air delivery (parachute drops)

c. External air transport (peculiar to helicopters).

The hazard relating to shock is greatest during landing. This may be the result of excessive downward velocity of the paradropped cargo, impact of the aircraft at moment of contact with the ground, or of arresting gear used to bring the aircraft to a stop. Normally, the magnitude of shock experienced by the aircraft is relatively small since the landing gear and arresting devices function as shock isolators. Paradrop slings incorporate a shock-mitigating cushion to protect the delivered cargo. Consequently, the maximum acceleration experienced by the cargo is often appreciably less than that imposed upon the carrier. It has been established that shock requirements under these conditions are a secondary factor.

FM 55-15 establishes the following cargo restraint factors which can be considered as equal to or in excess of the acceleration which would be imposed upon the cargo during normal flight or in the event of an emergency:

a. Forward: 8 *g*'s

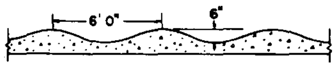
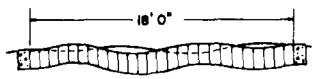
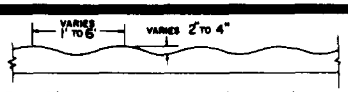
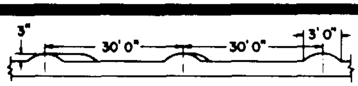
b. Sideward: 1.5 *g*'s

c. Vertical (up): 4.5 *g*'s

d. Vertical (down): 4.5 *g*'s

e. Aft: 2 *g*'s.

Impacts experienced by cargo subject to air delivery are controlled by introducing auxiliary shock-absorbing devices. Parachutes, and crushable pallets in combination, function to mitigate the impact imposed upon the cargo to a magnitude within the fragility level of the container. Calculations to deter-

| | TEST COURSE | PAYLOAD | SPEED, mph | MAXIMUM ACCELERATIONS VERTICAL G's | VERTICAL Hz | TRANSVERSE G's | TRANSVERSE Hz | LONGITUDINAL G's | LONGITUDINAL Hz |
|---|---|---|---|---|---|---|---|---|---|
|  Profile approaches a sine wave with a double amplitude of six inches and a complete cycle occurring every six feet for 800 feet of concrete. | 6" WASHBOARD | W/O | 5 | 1.6 at<br>2.7 at | 3<br>300 | 1.1 at | 1.3 | .3 at<br>3.6 at | 2<br>350 |
| | | W | 5 | 1.2 at<br>.8 at | 2.5<br>350 | 1.9 at | 220 | .5 at<br>.5 at | 13<br>300 |
|  Cobblestone road provides irregular, bumpy surface with crests placed to subject vehicle to both pitching and rolling motions for 3936 feet. | BELGIAN BLOCK | W/O | 20 | 1.1 at<br>.4 at | 11<br>300 | .3 at<br>.4 at | 6<br>450 | 1.6 at<br>1.9 at | 15<br>350 |
| | | W | 20 | .8 at<br>1.9 at | 2<br>350 | .4 at<br>1.5 at | 3<br>300 | .4 at<br>.3 at | 6<br>250 |
|  Two 90-degree radial turns incorporate symmetrical bumps varying from two to four inches in height and from one to six feet from crest to crest over a distance of 128 feet. | RADIAL WASHBOARD | W/O | 5 | .8 at<br>.5 at | 5<br>350 | .4 at | 450 | .9 at<br>.5 at | 2.5<br>300 |
| | | W | 5 | 1 at<br>.4 at | 2<br>350 | .3 at<br>.7 at | 2<br>150 | .4 at | 7 |
|  Series of rounded bumps three inches high and three feet wide are spaced 30 feet apart at various angles with respect to centerline of 831-foot course. | STAGGERED BUMP | W/O | 20 | 2.1 at<br>11.7 at | 4<br>250 | .5 at<br>2.4 at | 10<br>400 | 10.8 at | 350 |
| | | W | 20 | 7.6 at | 320 | 5.2 at | 250 | 6.1 at<br>1.1 at | 10<br>400 |
|  Cross country test imposes varying and irregular disturbances to help in evaluation of overall mounting system effectiveness. | TRUCK CROSS COUNTRY | W/O | 15 | .6 at<br>1.1 at | 5<br>450 | .7 at | 12 | .7 at<br>1.9 at | 10<br>350 |
| | | W | 15 | .3 at<br>.5 at | 5<br>400 | .6 at<br>.3 at | 25<br>110 | .3 at<br>.3 at | 1.5<br>250 |

Natural frequency vehicle suspension 1 to 3 Hz.
Accelerations measured at cargo bed of standard 2½-ton 6 × 6 military truck.
Both high and low-frequency disturbances shown.

Figure 3-6. Munson Road Test

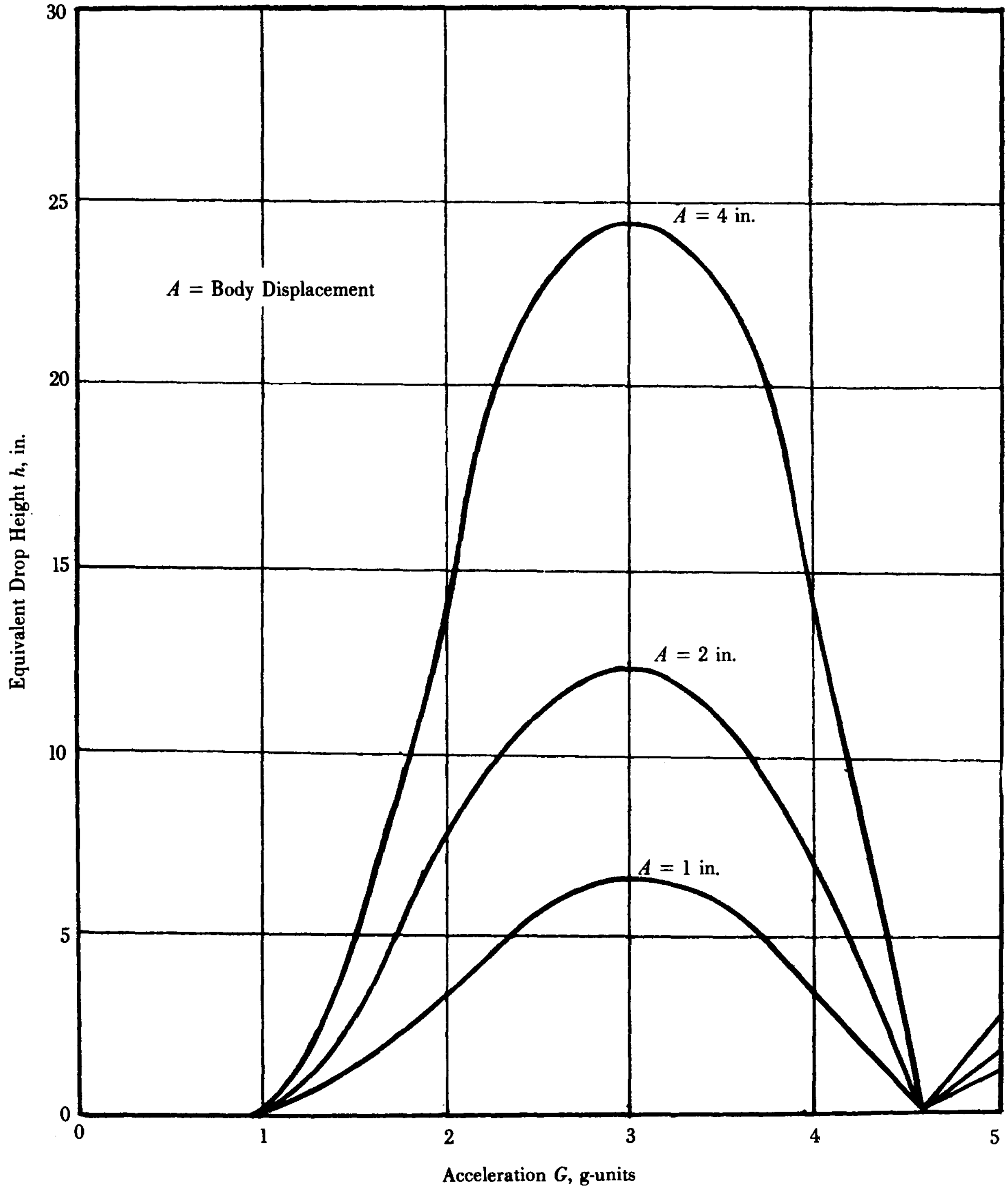



**Figure 3-7. Equivalent Drop Heights Corresponding to the Acceleration Forces Usually Found in Transit (A body moving only a short distance can land with an impact equal to a free fall many times greater.)**

mine the amount of auxiliary cushion required are based on assumed parachute drop velocities of 30 feet per second (fps) or 50 fps. These velocities are approximately equal to free-fall velocities from heights of 14 ft and 40 ft, respectively.

The predominant vibration in aircraft results from the propulsion system. The numerical values of these frequencies cover a wide range since they are dependent on the air velocity, the surface characteristics of the aircraft, and the natural frequencies of various structural components.

Other hazards to which air cargo is subjected include:

a. Temperature shock

b. Pressure differential as the result of altitude or sudden altitude change.

High speed, fast climbing aircraft subject their cargo to rapid and severe variations in both temperature and pressure. Most cargo aircraft have pressurized compartments. However, there is the possibility that the cargo may be subjected to the hazards described, and provision must be made to withstand the effects of these changes when required.

#### 3-2.3.4 Marine Vessel Shipments

Marine vessel shipment subjects cargo to hazards similar to and comparable in intensity to those of other modes of transportation in addition to those peculiar to this particular transport medium. The cargo ship is a floating warehouse; as such, it encompasses those hazards peculiar to in-plant handling and also those normally associated with warehouse storage. Efficient storage of cargo makes high stacking an economic necessity. In addition, mechanical handling devices subject the cargo to severe physical abuse—pendulum and extreme free-fall impacts are prevalent in cargo handling. Of particular concern are severe impact shocks—operating in a hostile environment, marine vessels are subject to ballistic shock resulting from noncontact underwater explosions.

An exact specification of ballistic shock does not appear possible. The general nature and maximum severity have been established by the shock motions of the high impact shock testing machines currently used to simulate the pertinent environment. The shock introduced by performance of the tests specified in MIL-S-901 represents the maximum probable within the marine environment. This test simulates the severity of shock encountered in naval service as represented by a velocity change of 100 in./s. This change is equivalent to a free-fall drop of 13.6 in., i.e.,

$$h = V^2/[2(368)],\text{in.} \tag{3-1}$$

as determined by Eq. 3-1.

If a shock-rise time of 3 ms is assumed, the imposed force of impact becomes approximately 84 *g*'s (see Chapter 1). Based on this information, one may consider a shock input resulting from ballistic shock as having a magnitude of 100 *g*'s.

The intensity of shock imposed upon shipborne cargo is, however, dependent upon the location and proximity of the cargo to the initial point of shock impingement. The magnitude of the imposed shock is attenuated as the shock wave travels through the ship structure.

The predominant steady-state vibration of the structural members of a naval vessel is caused by the propeller action and differs from one type of vessel to another. The maximum vibration frequency generally encountered is approximately 20 Hz. Suspension systems having a natural frequency of 25-30 Hz represent the currently accepted standard for naval applications.

In addition to the physical hazards prevalent in marine vessel transport, the cargo is subjected also to the deteriorating effects of an environment peculiar to the sea. Pier, deck, or hold storage subjects the cargo to the damaging effects of:

a. Sunshine

b. Rain

c. Humidity

d. Fungus

e. Salt fog

f. Immersion.

### 3-2.4 FIELD DEPOT STORAGE

Field depot storage sites expose materiel to severe conditions which result in deterioration of the container, causing degradation of its protective characteristics.

Field depots are often remote and, as such, may be lacking in materiel handling devices. Consequently, materiel may be subjected to severe shock resulting from rough and improvised handling.

Worldwide deployment encompasses all of the geographic regions and the peculiar aspects of their environments. Each environment introduces hazards peculiar to itself in addition to those hazards common to all environments. The hazards peculiar to geographic zones which materiel will encounter when exposed to the logistic pattern of worldwide distribution are many and varied. For a detailed discussion of environments see Refs. 1-5.

The tropics present a hot humid atmosphere subjecting materiel to what is commonly referred to as

"jungle rot". Excessive rainfall, high humidity, heat, and fungus in addition to the prevalence of vermin, insects, and reptiles all present problems relating to materiel protection and to the safety of personnel. The physical integrity of the container, often overlooked, cannot be compromised. Deadly snakes and germ-ridden rodents are known to nest within the confines of a container. Broken containers introduce this additional hazard not normally associated with materiel protection.

The Arctic regions subject materiel to a very cold atmosphere. Subzero temperatures of -65°F are common; temperatures of -85°F have been recorded in underground ammunition storage "igloos". The physical characteristics of the container components—in particular the protective seals and elastomeric mounts—are radically altered under these conditions, and the protective integrity of the container is jeopardized.

Consideration of moisture-laden air accumulating within the container is a hazard peculiar to all environments. Various devices and schemes have been developed to overcome the deteriorating effects of condensation on missiles and their components.

Peculiar to all regions are hazards caused by intentional abuse, often comprising sabotage. The container must provide protection to resist arson, detonation by small arms, penetration of the missile shell by BB shot, etc. Often the need to conceal the item is of prime import; security requirements often dictate the need for concealing the deployment of weapon systems.

## REFERENCES

1. AMCP 706-115, Engineering Design Handbook, *Environmental Series, Part One, Basic Environmental Concepts*.
2. AMCP 706-116, Engineering Design Handbook, *Environmental Series, Part Two, Natural Environmental Factors*.
3. AMCP 706-117, Engineering Design Handbook, *Environmental Series, Part Three, Induced Environmental Factors*.
4. AMCP 706-118, Engineering Design Handbook, *Environmental Series, Part Four, Life Cycle Environments*.
5. AMCP 706-119, Engineering Design Handbook, *Environmental Series, Glossary of Environmental Terms*.

# CHAPTER 4
# CONTAINER QUALIFICATION TESTS

*Environmental test methods for qualifying containers and purpose of the tests are described. Procedures for conducting the tests are outlined. Criteria for the rejection of containers failing the tests are presented.*

## 4-1 GENERAL

The objective of any test program is to qualify the test specimen by demonstrating its ability to satisfy the user's requirements. The test specimen must be a true representation of the end item and must perform to satisfy the operational, technical, and safety requirements in all of the environments of intended use. Qualification testing usually is performed on a prototype container having a dynamically simulated dummy or an inert missile or missile component encased within its confines.

Exposure of the test specimen to the hazards and environments of the actual logistic cycle is a costly, time-consuming process. To expedite the availability of new materiel, a test specimen of the developed prototype is subjected to laboratory tests that simulate the progressive abuse and longtime environmental exposure imposed upon the container by the logistic supply pattern. The level of abuse is a severe representation of some insignificant fraction of the logistic cycle.

Container performance evaluation encompasses a series of environmental tests which may be categorized under two general headings: mechanical and climatic. Those designated as mechanical subject the test specimen to physical abuse simulating the hazards associated with the anticipated methods of transit and handling. Those falling within the climatic category subject the specimen to the deteriorating effects of the projected environment peculiar to the geographic and spatial location in which it will operate. The conditions to which the specimen is exposed normally are set at a severe level to accelerate the effects of repetitive and progressive abuse, and the effects resulting from prolonged exposure.

Test procedures and test apparatus have been developed to simulate the operating environment conveniently within the laboratory. An assortment of mechanical devices and climatic chambers are currently available; these, in addition to electronic recording devices, constitute the tools required to conduct a scientific evaluation through controlled testing. The advance of container test technology becomes evident when the current state of the art is compared with the early "Ready-Test" method consisting of kicking the specimen down a flight of stairs.

Evaluation processes and acceptance criteria are based on comparison with established standards. The best standard would be the ideal container—one capable of providing complete protection, weighing nothing, lasting forever, and costing nothing. Obviously, the challenge is the development of the *optimum* container—one demonstrating both technical and economic feasibility.

Numerous attempts have been made to develop a test procedure applicable to all containers. The plethora of data available often is tailored to the specific contents of the container or to the environments peculiar to only limited application. Obviously, any effort to standardize procedure must start with a common factor peculiar to all applications. A survey and evaluation of data favor establishing as this basis the all-inclusive logistic pattern of the worldwide distribution policy.

Standard tests have been developed to simulate the effects of the environmental hazards experienced by containers during worldwide distribution. These tests encompass all situations and conditions prevalent in the Army's current logistic supply concept.

MIL-STD-810 *Environmental Test Methods* is typical of the many procedures available which delineate a comprehensive test program. Those tests pertinent to missile and rocket container evaluation are:

a. Rough Handling
b. Vibration
c. High Temperature
d. Low Temperature
e. Low Pressure
f. Rain
g. Sand and Dust
h. Salt Fog
i. Humidity
j. Sunshine
k. Fungus.

A test specimen, subjected to these tests in the sequence presented, can be considered as having been exposed to progressive abuse peculiar to the environment of worldwide distribution. The recommended

sequence provides for those factors relating to scheduling, time, cost, and the contingencies affecting most test programs. The recommended order may be modified to suit the prevailing situation; however, it is recommended that the rough handling test always precede the vibration test to introduce any loss of restraint experienced as the result of shock (see Chapter 7).

Regardless of the outcome of the test, it is mandatory that the procedure followed and the data generated be fully documented, certified, and witnessed. These data must be processed to provide input as a contribution to the state of the art.

The formulation of a particular test plan need not provide for subjecting the test specimen to all of the eleven tests specified. The use of materials and/or designs certified as having met the requirements of Department of Defense (DOD) Specifications may be considered as acceptable and need not be subjected to retest. The physical response and performance of such materials, functioning as an assembly, must however be evaluated. Obviously, a container assembly comprised of materials certifed to be fungous resistant and inert to salt fog deterioration or penetration need not be subjected to all eleven tests. However, a container comprised of material certified as adequate for high temperature applications must be subjected to shock testing at elevated temperature since the degradation of physical response may not be covered by the applicable specification.

Consequently, it behooves the designer to select only those tests applicable to the projected environment and to subject the test specimen only to those test conditions to which it has not previously been exposed. Obviously, the use of materials and techniques covered by DOD specification will minimize the test procedure; however, this practice should not in any way affect advances in the state of the art nor discourage the use of the best material for the proposed application.

The tests described in the paragraphs that follow do not constitute a standard or specification but merely summarize the terms, conditions, and requirements found in numerous uncoordinated qualifying test procedures.

## 4-2 ROUGH HANDLING TESTS

Rough handling tests are conducted to verify the structural integrity of the container in addition to establishing the degree of shock mitigation provided by the suspension system.

The rough handling tests to which the container is exposed have been developed to simulate the anticipated environment in which the container will operate. The magnitudes of established shock are based on the theory of probability which predicts the frequency and type of handling to be encountered.

The magnitude of shock as the result of rough handling is predicated on the weight of the container and the method by which it will be handled. By placing the container in its proper weight classification, an estimate of the severity of treatment it will receive can be made.

The tests, developed to simulate the required conditions, are described and discussed in subsequent paragraphs. No one test specimen need be subjected to all of the tests specified since some of the tests produce the same effects and are pertinent only to test specimens of a specific size; e.g., a small container which can be conveniently subjected to a free-fall flat-end drop need not be subjected to the pendulum impact test which pertains to large, unwieldy containers. In both instances, the impact imposed upon the specimen will be comparable in magnitude. A test selection chart, Table 4-1, has been included to assist in the development of a test plan; however, the guidance provided is contingent upon the characteristics of the container and the proposed application and environment.

### 4-2.1 KINDS OF TESTS

Rough handling tests comprise the following:

1. Corner Free-Fall Drop
2. Flat-Face Free-Fall Drop
3. 45-deg Free-Fall Drop
4. Edge-Drop Free Fall
5. Pendulum Impact
6. Edgewise Rotational Drop
7. Cornerwise Rotational Drop
8. Inclined Impact (Conbur)
9. Tip-Over
10. Rollover
11. Rolling Impact
12. Serviceability.

Each test is described in detail.

Those containers likely to be affected by temperature and humidity extremes shall be conditioned prior to shock testing at those temperatures peculiar to their projected environments. The temperature and humidity environments peculiar to the established worldwide distribution environment are shown in Table 4-2. The procedure for conditioning of test specimens is included in the paragraphs of this chapter relating to High Temperature Test and Low Temperature Test, pars. 4-4 and 4-5, respectively.

**TABLE 4-1. TEST SELECTION CHART**

| Test | Containers Weighing Less than 200 lb Gross Weight: No Dimension Greater than 60 in. | Containers Weighing Less than 200 lb Gross Weight: With Dimensions Greater than 60 in. | Containers With Gross Weight in Excess of 200 lb |
|---|---|---|---|
| a. Rough Handling | | | |
| (1) Corner Free-Fall Drop | Required | Not Applicable | Not Applicable |
| (2) Flat-Face Free-Fall Drop | Performed at the discretion of the responsible agency | | |
| (3) 45-deg Free-Fall Drop | Required | Required | Not Applicable |
| (4) Edge-Drop Free Fall | Performed at the discretion of the responsible agency | | |
| (5) Pendulum Impact | Not Applicable | Required | Required |
| (6) Edgewise Rotational Drop | Not Applicable | Required | Required |
| (7) Cornerwise Rotational Drop | Not Applicable | Required | Required |
| (8) Inclined Impact (Conbur) | Not Applicable | Used in lieu of Pendulum Impact when required apparatus is available. | |
| (9) Tip-Over<br>(10) Rollover<br>(11) Rolling Impact<br>(12) Serviceability | Performed at the discretion of the responsible agency | | |
| b. Vibration | Required | Required | Required |
| c. High Temperature | Performed in conjunction with shock testing | | |
| d. Low Temperature | Performed in conjunction with shock testing | | |
| e. Low Pressure | Required for all sealed containers. Applicable where performance of components is jeopardized. | | |
| f. Rain | Applicable to all containers except those that are sealed | | |
| g. Sand and Dust | Performed at the discretion of the responsible agency | | |
| h. Salt Fog | Performed at the discretion of the responsible agency | | |
| i. Humidity | Applicable to all containers except those that are sealed | | |
| j. Sunshine | Performed at the discretion of the responsible agency | | |
| k. Fungus | Performed at the discretion of the responsible agency | | |

References: MIL-STD-810, MIL-STD-331, MIL-P-116, MIL-S-901, FED-STD-101

Containers whose function is to protect fragile, sophisticated materiel must include—as part of shock testing—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

Damage to materiel and to their containers often can be determined by visual examination and an evaluation of serviceability determined; however, to conduct a scientific evaluation to assure reliability of performance, instrumentation of the test specimen is required.

Instrumentation and data recording are not within the scope of this handbook; however, it shall suffice to state that an assortment of transducers (accelerometers, thermocouples, vibration pickups, and shock recorders) is available. These instruments may be fastened to and/or included within the test specimen to pick up and, in conjunction with auxiliary

**TABLE 4-2. SUMMARY OF TEMPERATURE AND RELATIVE HUMIDITY DIURNAL EXTREMES (AR 70-38)**

| Climatic Category | Operational Conditions | | Storage and Transit Conditions | |
|---|---|---|---|---|
| | Ambient Air Temperature, °F | Ambient Relative Humidity, % | Induced Air Temperature, °F | Induced Relative Humidity, % |
| Wet-Warm | nearly constant 75° | 95 to 100 | nearly constant 80° | 95 to 100 |
| Wet-Hot | 78° to 95° | 74 to 100 | 90° to 160° | 10 to 85 |
| Humid-Hot Coastal Desert | 85° to 100° | 63 to 90 | 90° to 160° | 10 to 85 |
| Hot-Dry | 90° to 125° | 5 to 20 | 90° to 160° | 2 to 50 |
| Intermediate Hot-Dry | 70° to 110° | 20 to 85 | 70° to 145° | 5 to 50 |
| Intermediate Cold | −5° to −25° | tending toward saturation | −10° to −30° | tending toward saturation |
| Cold | −35° to −50° | tending toward saturation | −35° to −50° | tending toward saturation |
| Extreme Cold | −60° to −70° | tending toward saturation | −60° to −70° | tending toward saturation |

apparatus, record the magnitude and characteristics of the imposed shock.

The drop heights in Table 4-3 (from MIL-P-116) are pertinent to those tests relating to free-fall and are applicable where specified.

### 4-2.2 CORNER FREE-FALL DROP TEST

The corner free-fall drop test (see Fig. 4-1) is applicable to containers weighing less than 200 lb and having no dimension greater than 60 in. The impact generated by the free-fall drop subjects the structure of the container to a damaging force comparable to that experienced during worldwide distribution. The effects of this abuse are more deleterious to the container than to its contents. Consequently, ***this test reflects only upon the structural integrity of the container shell and does not establish the degree of protection provided to the container contents.*** The structural components of the container shell absorb a major portion of the force resulting from the concentrated impact of a corner drop. Very little of this force is transmitted to the contents or to any intermediate shock-mitigating media. The force of impact is dissipated by distor-

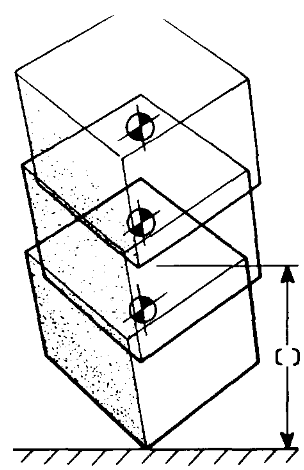


**Figure 4-1. Corner Free-Fall Drop Test**

**TABLE 4-3. GRADUATED DROP AND IMPACT TEST HEIGHTS**

| Gross Weight of Container and Contents $W$, lb | Edgewise Drop (2 drops each end) | Cornerwise Drop Test (2 drops on each of 2 diagonally opposite corners of bottom) | Impact Tests (1 impact on each of 2 opposite ends) (Use either test.) | |
|---|---|---|---|---|
| lb | Height of Drop, in. | Height of Drop, in. | Pendulum Impact, in. | Incline Impact, ft |
| $0 < W \leq 250$ | 30 | 30 | 14 | 7.0 |
| $250 < W \leq 500$ | 24 | 24 | 11 | 5.5 |
| $500 < W \leq 1000$ | 18 | 18 | 8 | 4.0 |
| $W > 1000$ | 12 | 12 | 5 | 2.5 |

*The US Army Development and Proof Services of Aberdeen Proving Ground has stated that a drop height of 60 in. be substituted for the above when the container will be subject to truck transportation. This is particularly applicable to sophisticated missiles and/or missile components regardless of their weight. (See MIL-STD-331.)

tion, fracture, or crushing of the container shell. The test is described in FED-STD-101.

#### 4-2.2.1 Procedure

The container shall be dropped cornerwise from a height as determined by its weight and size classification (see Table 4-3). Impact shall be on a steel, concrete, or stone surface of sufficient mass to absorb the shock without deflection in such a manner that the corner of the container absorbs the full force of the fall. This test shall be repeated until each of the eight corners of the container has received a fall. (The height of drop specified refers to the distance from the impacting surface to the nearest corner of the container when suspended prior to the fall.) The fall shall be a free-fall, i.e., no ropes or other suspending media are attached to the container during the fall.

If the container is of the drum type, the top and bottom of the drum shall be marked so that the circle of the top and bottom is quartered, and the test shall be applied to each of the quartered sections.

Containers whose function is to protect fragile, sophisticated materiel must include—as a part of the test—methods and means by which the magnitude and the characteristics of the imposed shock and that experienced by the contents may be measured.

#### 4-2.2.2 Criteria for Rejection

Any damage to materials and components or evidence of displacement which affects the utility of the container and/or its method of preservation shall constitute cause for rejection. Damage to or operational malfunction of the contained contents shall constitute a failure.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.3 FLAT-FACE FREE-FALL DROP TEST

The flat-face free-fall drop test (see Fig. 4-2) is used to establish the maximum protection provided by the container assembly. *This test is used primarily to establish the protective level of the container and/or the suspension system.* Corner drops have a more deleterious effect on the container than do flat-face drops; however, *flat drops will cause greater damage to the suspended contents.* With proper instrumentation, the transmissibility (efficiency) of the container assembly can be

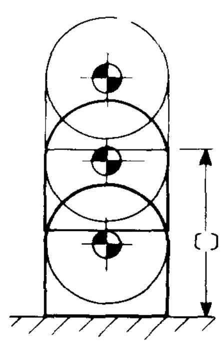


**Figure 4-2. Flat-Face Free-Fall Drop Test**

determined and used to verify the analytical design calculations. The performance of *this test is not mandatory*, and the acceptance criteria need not provide for this simulation of projected rough handling. The effects of this test and the data generated will, however, provide conclusive information to evaluate the test specimen effectively. The test is described in FED-STD-101.

#### 4-2.3.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The container shall be dropped from a vertical distance as determined by its weight classification for free-fall drops (see Table 4-3). The test specimen shall be allowed to fall freely onto a concrete or similarly hard surface such that the container strikes flat on its skids or the surface involved. This test shall be limited to only two drops; one flat drop on the bottom plus one flat drop on one end.

#### 4-2.3.2 Criteria for Rejection

Damage to or operational malfunction of the contained contents shall constitute a failure. The recorded data generated relating to transmissibility of the shock of impact shall not subject the contents to a force in excess of its established fragility level.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.4 45-deg FREE-FALL DROP TEST

The 45-deg free-fall drop test (see Fig. 4-3) subjects the test specimen to abuse common to materiel in transit. The forces imposed upon the container are indicative of those experienced by rough handling; in particular, tailgate unloading. The test is described in FED-STD-101.

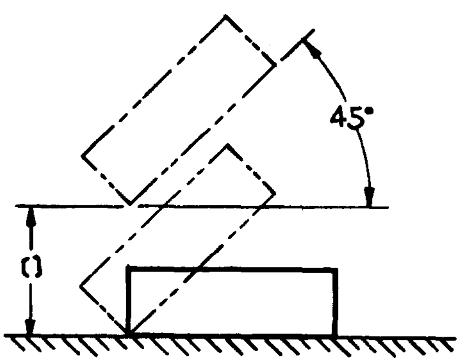



**Figure 4-3. 45-deg Free-Fall Drop Test**

This test is *applicable to all containers under 200 lb regardless of length*, which because of their configuration can be manhandled.

The test procedure imposes an impact force on the leading edge of the test specimen followed by a rotational drop subjecting the aft end to a secondary impact, often of greater magnitude.

#### 4-2.4.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test specimen shall be elevated to a height equivalent to that specified in the weight classification table, Table 4-3, for free-fall drops. That side of the container having the greatest surface area shall be positioned parallel to the impacting surface. That side with the longest dimension shall be elevated at one end to form a 45-deg angle between the impacting surface and the longest side of the container. The test specimen shall be dropped from this position onto the rigid nonyielding impacting surface, subjecting the container to first a primary shock at one end and a subsequent secondary shock at its opposite end. This test shall be conducted twice, subjecting each end to both a primary and secondary shock.

#### 4-2.4.2 Criteria for Rejection

Components or evidence of displacement which affects the utility of the container and/or its method of preservation shall constitute cause for rejection. Damage to or operational malfunction of the contained contents shall constitute a failure.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.5 EDGE-DROP FREE-FALL TEST

The edge-drop free-fall test (see Fig. 4-4) is applicable to situations where *it is preferable to increase gradually the level of shock applied to the container*. The effects of this test are less severe than either the corner or flat-face impact. The performance of *this test is not mandatory*, and its inclusion in any test program is at the discretion of the responsible agency and shall be conducted only in conjunction with subsequent

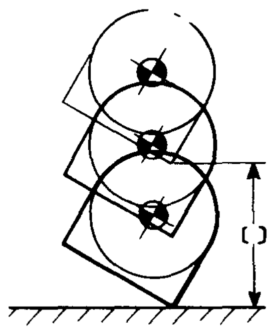


Figure 4-4. Edge-Drop Free-Fall Test

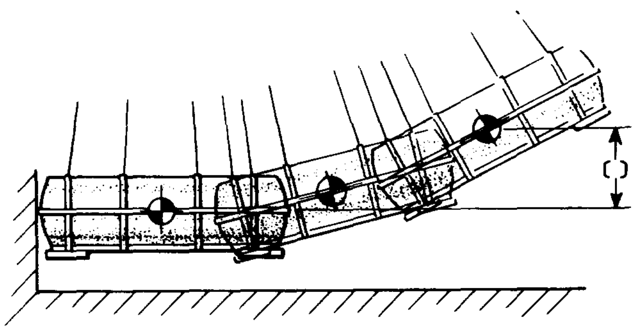


Figure 4-5. Pendulum Impact Test.

corner drop tests. The test is described in FED-STD-101.

#### 4-2.5.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test specimen shall be raised the vertical distance as determined by its weight classification such that the container is suspended with the center of gravity vertically above the striking edge. The container shall be allowed to fall freely to a concrete or similarly hard surface, striking edge first. The test shall be applied to two diagonally opposite edges.

#### 4-2.5.2 Criteria for Rejection

Any damage to the container or to its contents shall be cause for rejection. However, *satisfactory performance does not qualify the test specimen* which must be further subjected to the corner free-fall drop test.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.6 PENDULUM IMPACT TEST

The pendulum impact test (see Fig. 4-5) is *applicable to all containers* whose *length exceeds 60 in.* and to those containers whose *weight exceeds 200 lb.* Containers too large or too heavy to subject to free-fall testing and *for which no Conbur* (Incline Impact Testing Device) is available may be tested by a pendulum device suspended from overhead. The test is described in FED-STD-101.

#### 4-2.6.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test specimen shall be suspended by 4 or more ropes or cables, 16 ft or more long. The suspended container shall be pulled back so that the center of gravity will have been raised the distance at least equivalent to that specified as drop height in the weight classification table, Table 4-3. The container shall be released allowing the end surface or skid, whichever extends farther, to strike on an unyielding barrier of concrete or similarly hard material that is perpendicular to the container at impact. One impact shall be applied to each end.

#### 4-2.6.2 Criteria for Rejection

Damage to either the container or to its contents which affects the functional performance of either, shall be cause for rejection.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.7 CORNERWISE ROTATIONAL DROP TEST

The cornerwise rotational drop test (see Fig. 4-6) is *applicable to all containers* whose *length exceeds 60 in.* and to those containers whose *weight exceeds 200 lb.* This modified drop test subjects the container to abuse typical of that produced by mechanized handling. The effects upon the container are of sufficient magnitude to demonstrate the structural integrity of the outer shell.

#### 4-2.7.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude

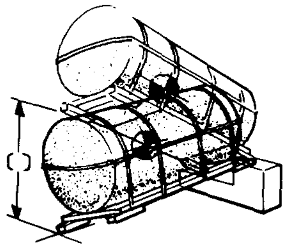


Figure 4-6. Cornerwise Rotational Drop Test

and characteristics of the imposed shock and that experienced by the contents may be measured.

The container shall be supported at one corner of its base on a sill or block 5 in. in height. The other corner of the same end shall be supported by a 12-in. sill or block. The lowest point of the opposite end shall be raised to the vertical height as specified in the weight classification table, Table 4-3, and allowed to fall freely onto a concrete or similarly hard surface. If the size of the container and the location of its center of gravity prevent dropping from the prescribed height, the greatest attainable height shall be the height of drop. One drop shall be applied to each of the four corners.

#### 4-2.7.2 Criteria for Rejection

Any damage to materials and components or evidence of displacement which affects the utility of the container and/or its method of preservation shall constitute cause for rejection. Damage to or operational malfunction of the contained contents shall constitute a failure.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.8 EDGEWISE ROTATIONAL DROP TEST

The edgewise rotational drop test (see Fig. 4-7) is *applicable to all containers* whose *length exceeds 60 in.* and to those containers whose *weight exceeds 200 lb.* This modified drop test is applied to large containers which would not be handled manually in any phase of transportation. The effects produced simulate the abuse of mechanized handling and provide a means to evaluate the mitigating characteristics of the container assembly.

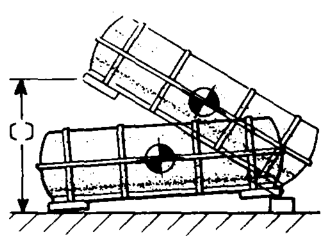


Figure 4-7. Edgewise Rotational Drop Test

#### 4-2.8.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The container shall be supported at one end of the base on a sill or block 5 in. in height and at right angles to the skids. The opposite end shall be raised to the vertical height specified in the weight classification table, Table 4-3, and allowed to fall freely onto a concrete or similarly hard surface. If the container size and center of gravity location prevent dropping from the prescribed height, the greatest attainable height shall be the height of drop. Two drops shall be applied to each end.

#### 4-2.8.2 Criteria for Rejection

Damage to either the container or its contents which affects the functional performance of either or both shall be cause for rejection.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

### 4-2.9 INCLINED IMPACT OR CONBUR TEST

The inclined impact or Conbur test (see Fig. 4-8) may be applied to containers whose length exceeds 60 in. or whose weight is in excess of 200 lb. This test is used to determine the ability of the container and its suspension system to protect the contents when subjected to impact stresses. The apparatus provides for the container to be placed on a dolly that rolls down a 10-deg incline against a rigid barrier to simulate the longitudinal shocks encountered in transit.

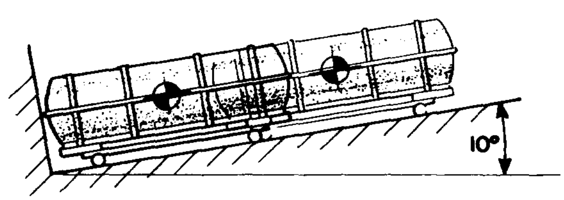



Figure 4-8. Inclined Impact or Conbur Test

The force of impact is controlled by the length of run (up to 25 ft).

### 4-2.9.1 Procedure

Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

The test shall be in accordance with FED-STD-101. The travel distance on the incline impact testing device shall be as indicated for the weight specified in Table 4-4.

The ability to perform this test is predicated on the availability of the required apparatus. *The Pendulum Impact Test may be used to produce the same effects should the required equipment be unavailable.*

### 4-2.9.2 Criteria for Rejection

Damage to either the container or its contents which affects the functional performance of either shall be cause for rejection.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

**TABLE 4-4**
**GRADUATED IMPACT TEST-DOLLY RUN**

| Gross Weight of Container $W$, lb | Incline-Impact Dolly Run, ft |
|---|---|
| $0<W\leq250$ | 7.0 |
| $250<W\leq500$ | 5.5 |
| $500<W\leq1000$ | 4.0 |
| $W>1000$ | 2.5 |

## 4-2.10 OPTIONAL ROUGH HANDLING TESTS

The tests that follow are included to acquaint the reader with other less sophisticated tests often used to evaluate the integrity and performance of containers designed to provide a low level of shock-mitigating protection.

These tests can be applicable to rocket and missile containers only *in preparation for subsequent qualifying evaluation*. On occasion, it may be preferable to increase the magnitude of abuse gradually in order to determine the feasibility of the test item to satisfy the performance requirements. Critical, expensive, and/or erratic test specimens may not permit immediate application of the full magnitude of the required force and a gradual, cautious approach may be required. Containers whose function is to protect fragile, sophisticated materiel must include—as part of the test—methods and means by which the magnitude and characteristics of the imposed shock and that experienced by the contents may be measured.

### 4-2.10.1 Tip-Over Test

The container, erect on its base, shall be slowly tipped (in the direction specified) until it falls freely and solely by its own weight to a concrete or similarly hard floor (see Fig. 4-9).

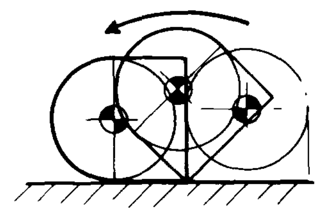


**Figure 4-9. Tip-Over Test**

### 4-2.10.2 Roll-Over Test

The container, erect on its base, shall be tipped sideways until it falls freely and solely of its own weight to a concrete or similarly hard surface (see Fig. 4-10). This shall be repeated with falls from the side to top, from top to the other side, and from the other side to the base—thus completing one revolution.

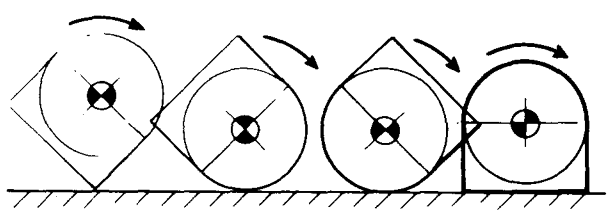


**Figure 4-10. Roll-Over Test**

### 4-2.10.3 Rolling Impact Test (Cylindrical Containers)

The container shall be allowed to roll down an incline on its rolling flanges and shall strike a vertical rigid flat surface at 10 ft/s (see Fig. 4-11).

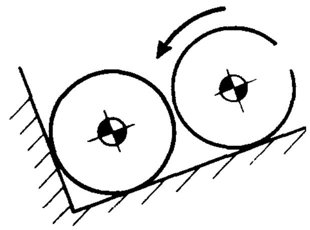


**Figure 4-11. Rolling Impact Test**

#### 4-2.10.4 Criteria for Rejection

Any damage to the container or to its contents shall be cause for rejection. However, satisfactory performance does not qualify the test specimen which must be further subjected to the required qualifying procedure.

Undesirable response characteristics including accelerations in excess of the established $G_m$ limits, indicating inadequate isolation of the container contents from shock environment, shall be cause for rejection.

## 4-3 SERVICEABILITY TESTS

The tests described in the paragraphs that follow simulate the conditions which are prevalent in a logistic environment. The integrity of the container structure and its components are evaluated by subjecting the test specimen to the abuse described. These tests are applicable to containers whose configuration includes characteristics falling within the scope of the particular test and permits the assessment of handling compatibility.

### 4-3.1 CONCENTRATED LOAD TEST (Stacking)

Completed packs or pallet loads shall be loaded in a manner to simulate a height of stack of at least 15 ft, allowed to stand overnight, removed, and examined for damage. Containers constructed of materials likely to be affected by humidity shall be tested at a minimum of 90% relative humidity at 90°F + 5 deg F and allowed to stand 24 h before the stacking test operation. Broken seals or barriers, damage to items, or deformation of container which prevents removal of the item shall be cause for rejection. Seals shall be checked for leaking before and after tests.

### 4-3.2 FORKLIFTING TEST

Loaded containers and completed packs, which have skids and fork pockets, and palletized unit loads shall be lifted clear of the ground and transported a distance of at least 50 ft and lowered. When palletized unit loads are tested, the test shall be conducted four times—i.e., forks entering the pallet form at each of the four sides of the unit load. Any tendency for forks to puncture the container, or for the container or unit load to be unstable while on the forks, or for difficulty in inserting or removing forks shall be cause for rejection. This test shall be conducted after the container or unit load has been subjected to all applicable rough handling, vibration, and stacking tests.

### 4-3.3 HOISTING TEST

Containers having hoisting attachments shall be tested as follows. The container shall be loaded with five times its normal load and hoisted free from the floor, held for at least 2 min, and lowered. Any breaking or permanent deformation shall be cause for rejection. Containers having handles shall be hoisted in like manner except that the load shall be two times the normal weight.

### 4-3.4 PUSHING AND TOWING TEST

Loaded shipping containers weighing more than 150 lb and all skidded containers shall be subjected to a sliding test. The loaded container or completed pack shall be tested by pulling across at least 5 ft of rough concrete. The test shall consist of pulling the container a distance of 5 ft or more axially, and 5 ft or more normally to the axis of the skids or to the major axis of nonskidded containers. Failure of this test shall be considered to have occurred if: (1) the skids or the bottom of the container receive damage other than minor scuffing and scoring, (2) any strapping or closing components of the container are broken or loosened, (3) the contents have been damaged, or (4) there is any irreparable damage to the container if it is a reusable type.

### 4-3.5 VIBRATION TEST

The reliability requirements for missile and rocket containers are much more stringent than those established for commercial packaging. Inadequate protection or malfunction of the container assembly can result in mission failure. Conditions causing failure resulting from vibratory fatigue are prevalent within the environment of worldwide distribution. The severity of vibrations peculiar to this logistic pattern has been increasing with the advent of new modes and methods of transportation.

Empirical data are available (see Chapter 3) to estimate the probable environment and the forces imposed upon the container by this environment. These data and the predictions resulting from their applica-

tion become the basis for design criteria and qualifying test procedure. These predictions have been expanded to provide a qualifying test procedure applicable to containers subject to the environment of worldwide distribution.

The purpose of this effort is to establish reliability-by-test; however, satisfactory performance does not necessarily imply optimum design since reliability through overdesign is not identified easily. The tests merely subject the test specimen to forces which are comparable to those which in its projected environment will produce fatigue failures. This exercise provides the designer with an experimental tool to evaluate design predictions and to discover unexpected phenomena sufficiently early to take corrective action.

The test procedure presented is concerned only with the evaluation of container performance—particularly, its suspension system. This test *does not* comprise a valid basis for evaluation of the ability of the contained contents to withstand the effects of the imposed vibrations. The final results of testing will provide evidence to evaluate the structural integrity of the container and its components, and an assessment of its performance to limit the transmissibility of the imposed vibration.

The test is a simulation of the vibrations encountered in shipment and not a duplication of the anticipated operating environment. To provide a realistic simulation, time scales have been reduced and the severity of imposed forces increased to introduce the concept of cumulative fatigue. It has been established that all vibrations imposed upon test specimens, subject to a military environment, shall be of the sinusoidal type. In addition, those frequencies pertinent to normal logistic transport are limited to the 5- to 500-Hz range. Acceptance of these postulates minimizes the test procedure and provides a practical simulation of actual service conditions. Refer to MIL-STD-810, Method 514.2, for detailed test procedures.

### 4-3.5.1 Procedure

The test procedure is comprised of three distinct phases, namely:

a. Resonancy Survey. This survey subjects the test specimen to the complete range of frequencies peculiar to the environment of worldwide distribution (5-500 Hz). The magnitude of vibratory input specified is that most prevalent in the various frequency environments—ship, rail, truck, and air transport. This survey identifies those critical frequencies at which the response of the test specimen and the frequency of the excitation input produce or approach a resonant state (see Chapter 1). It is these frequencies at which fatigue failure is most prevalent.

b. Suspension Proof Test. The second phase of the test subjects the container to those critical frequencies producing resonance and the maximum amplitudes associated with this phenomenon. The suspension system, when exercised under these conditions, may be considered as having been subjected to the cumulative effects of the forces it will experience in its projected environment. The ratio of test time to service life has been statistically derived according to D&PS Report No. 1190, *The Development of an Engineering Test Standard Covering the Transportation Environment of Material*, and provides a test duration established at 15 min in each plane. By exercising the test specimen at resonant frequency with the inputs specified for a duration of 15 min, it can be assumed that the effects due to resonance, comparable to the life span of the container, have been simulated.

Since test severity is directly related to response amplitude, it is only necessary to vibrate where response amplitude is the greatest—i.e., at the lowest resonant frequency.

c. Interpretation of Test Data. The final phase of the vibration test relates to the reduction of recorded data to allow for the evaluation of performance and assessment of reliability.

The test specimen shall be instrumented with vibration-measuring pickups to detect and define critical resonances and associated vibration mode shapes. Instrumentation shall consist of at least three accelerometers strategically located to detect the response of the container contents in each of its three orthogonal axes—longitudinal, lateral, and vertical.

The test specimen shall be fastened securely to the vibration machine exciter head (use of slip table permissible only if head mounting is impossible). Attachment shall be by means of a rigid fixture capable of transmitting the specified vibrations.

### 4-3.5.2 Specific Tests

#### 4-3.5.2.1 Resonancy Survey (Scanning)

A survey to determine critical resonant frequency will be accomplished with the overpack alternately positioned in its: (1) longitudinal axis and (2) vertical axis. Excitation shall be applied in each axis throughout the frequency range of 5-500-5 Hz. Sweep duration and vibratory inputs shall be as specified in Table 4-5.

TABLE 4-5. SCANNING

| | |
|---|---|
| 35 min — | Sweep 5-52-5 Hz at 1.3 $g$ input with two 17.5-min cycles, limited by 1 in. in DA. |
| 35 min — | Sweep 5-52-5 Hz at 1.6 $g$ input with two 17.5-min cycles, limited by 1 in. in DA. |
| 6 min — | Sweep 5-52-5 Hz at 2.5 $g$ input with one 6-min cycle, limited by 1 in. in DA. |
| 45 min — | Sweep 52-500-52 Hz at 2.5 $g$ input with three 5-min cycles, limited by 1 in. in DA. |

If one or more resonances are determined, a cushioning proof test shall be conducted in the applicable axis and at the lowest resonant frequency.

If a specific resonant condition is not found in the resonant survey, the overpack shall be positioned longitudinally and vibrated under the conditions of 268 cycles per minute (5 Hz) for a period of 30 min (at 70°F ±5 deg F). Repeat this test with overpack positioned vertically.

#### 4-3.5.2.2 Cushioning Proof Test

Vibrate at the established resonant frequency with the test specimen positioned in its longitudinal plane; repeat with the specimen in the vertical plane:

a. 7.0 min at 1.3 $g$ input
b. 6.5 min at 1.6 $g$ input
c. 1.5 min at 2.5 $g$ input.

### 4-3.5.3 Interpretation of Test Data

Any of the following conditions shall be cause for rejection:

a. Transmissibility of excitation forces in excess of factor of 5 during proof test

b. Evidence of damage which would affect the utility of the container

c. Recorded force imposed upon the protected item exceeds its $G_m$ limit.

These criteria establish representative laboratory vibration time for distance (mileage) traveled by the missile container in both military transport media and common carriers. The approach used was to determine the reasonable worldwide distribution travel distance and apply the vibration time as related to that distance (see Table 4-6). The data in Table 4-6 are a result of a US Army Materiel Command study.

## 4-4 HIGH TEMPERATURE TEST

High temperature testing is conducted to determine the resistance of the container and its components to elevated temperatures that may be encountered in the environment of worldwide distribution.

High temperature conditions may cause rubber, plastic, and plywood to discolor, crack, bulge, check, or craze. Closure and sealing strips may partially melt and adhere to mating parts. Packing and gaskets may take a permanent set. Cushions may collapse, and distortion of structural components may result. Of particular interest is the degradation of the physical response of the cushioning system. The resiliency of metallic springs and that of natural and synthetic elastomers fluctuates with temperature change. Consequently, the test procedure delineated may be performed to determine the effects of high temperature exposure of the test specimen; *however, in container evaluation, this phase normally is performed in conjunction with rough handling tests*. One phase of the rough handling tests requires that the test specimen be conditioned at high temperature prior to subjecting it to rough handling. As such, the conditioning phase preceding the rough handling tests is equivalent to the exposure required for high temperature testing and *need not be* conducted separately unless so specified. The effects of high temperature exposure can be evaluated after the rough handling tests have been conducted and the specimen has cooled to room temperature.

### 4-4.1 PROCEDURE

The test specimen shall be placed within a climatic chamber and conditioned to 160°F (71°C) for a period of 48 h or until it has been determined that the container has stabilized at the specified temperature. Conditioning of the specimen shall not be accelerated by raising the nominal temperature of the chamber temperature input beyond the extreme limit of the range specified. The test specimen shall then be removed from the conditioning chamber (*subjected to rough handling tests*) and, upon return to room temper-

TABLE 4-6. VIBRATION DATA vs DISTANCE OF TRAVEL

| Distance, mi | Mode | Input, g-units | Time | Vibration Time, min | Time at Resonance, min | Time Scanning, min |
|---|---|---|---|---|---|---|
| 8500 | Ship, Aircraft | 1.3 | 10 min/1000 mi | 85 | 14 | 71 |
| 4000 | Track and Truck (military convoy) | 1.6 | 20 min/1000 mi | 80 | 13 | 67 |
| 1000 | Trailer (2-wheeled) | 2.5 | 15 min/1000 mi | 15 | 2.5 | 12.5 |
| 100 | Helicopter (75 mph) | 2.5 | Actual | 80 | 0 | 80 |

ature, examined for damage. See MIL-STD-810, Method 501.1, for the detailed procedure.

### 4-4.2 CRITERIA FOR REJECTION

Damage to the container resulting from this exposure or to any of its components which could in any manner prevent the test item from meeting operational requirements shall provide reason to consider the test item as having failed to withstand the conditions of the test.

## 4-5 LOW TEMPERATURE TEST

The low temperature test is conducted to determine the effects of low temperature on the container and its components during storage and service use. Differential contraction of metal parts and loss of resiliency of packings and gaskets are two of the principal difficulties associated with low temperatures. In addition, the physical characteristics of elastomeric mounts are radically altered under these conditions and the protective integrity of the container is jeopardized.

The Arctic regions subject materiel to a very cold atmosphere. Subzero temperatures of −65°F (−54°C) are common; temperatures of −85°F (−65°C) have been recorded in underground ammunition storage "igloos". For worldwide distribution, −70F° (−57°C) has been established as standard.

The test procedure specified may be applied to determine the effects of low temperature exposure upon the test specimen; however, *in container evaluation, this normally is performed in conjunction with rough handling testing*. One phase of the rough handling tests requires that the test specimen be conditioned at low temperature prior to subjecting it to rough handling. As such, the conditioning phase preceding the rough handling tests is equivalent to the exposure required for low temperature testing and *need not be* conducted separately unless so specified. The effects of low temperature exposure can be evaluated after the rough handling tests have been conducted and the test specimen has stabilized at ambient temperature.

### 4-5.1 PROCEDURE

The test specimen shall be placed within a climatic chamber and conditioned to −70°F (−57°C) for a period of 24 h or until it has been determined that the container has stabilized at the specified temperature. Conditioning of the specimen shall not be accelerated by lowering the nominal chamber temperature input beyond the extreme limit of the range specified. The test specimen shall then be removed from the conditioning chamber (*subjected to rough handling tests*) and, upon return to room temperature, examined for damage. See MIL-STD-810, Method 502.1, for the detailed procedure.

### 4-5.2 CRITERIA FOR REJECTION

Damage to the container resulting from this exposure or to any of its functional components which could in any manner prevent the test item from meeting operational requirements shall constitute cause for rejection.

## 4-6 LOW PRESSURE TEST

The low pressure test is conducted to determine the ability of the container and its components to withstand the reduced pressure encountered during shipment by air and the low pressure conditions found at high ground elevations.

Damaging effects of low pressure include leakage through sealed enclosures, rupture of pressurized containers, degassing and collapse of closed cell plastic cushion compounds, overexpansion and rupture

of air bag suspensions, etc. Low density materials may change their physical and chemical properties.

The structural integrity of free-breathing containers normally is unaffected by reduced pressure; however, the effects upon the functional components and their performance must be established.

Exposing controlled-breathing containers to low pressure tests exercises the control valves to permit verification of operating pressures. Proper functioning of the breather valves relieves the structure of abnormal stresses and protects the contents from the deleterious effects of reduced pressure.

Pressurized sealed containers are tested to evaluate the effectiveness of the protective seals and gaskets in addition to demonstrating the ability of the container to withstand the pressure differential imposed upon its structure.

### 4-6.1 PROCEDURE

The test specimen shall be examined under standard ambient conditions and a record made of all data necessary to determine compliance with required performance.

Pressurized containers and those equipped with controlled-breathing devices shall contain a gage or recording device to permit monitoring of internal pressure. Pressurized containers shall be charged to the required level. Controlled-breathing containers shall be sealed under ambient conditions and the level of internal pressure recorded.

The test specimen shall be placed in the test chamber and positioned in a manner that will simulate air transit conditions. The internal chamber temperature shall be uncontrolled during the test. The chamber internal pressure shall be reduced to 16.9 in. of mercury (15,000 ft) and maintained for not less than 1 h. If a sudden loss of pressure in the cargo compartment could cause failure of the test item which could damage the aircraft, the test specimen will be tested to withstand an altitude of 40,000 ft (5.54 in. of mercury). The internal pressure of sealed containers (pressurized and controlled breathing) shall be monitored and their values recorded. The chamber shall then be returned to room pressure and the test item inspected. See MIL-STD-810, Method 500.1, for the detailed procedure.

### 4-6.2 CRITERIA FOR REJECTION

Deterioration of any component which could in any manner prevent the equipment from meeting functional, maintenance, and service requirements during service life shall provide reason to reject the equipment for having failed to comply with the conditions of the test.

Pressurized sealed containers shall experience no pressure drop during the 1-h exposure period and shall indicate an initial charge gage reading when returned to room pressure.

Containers equipped with controlled breathing shall maintain their initial pressure level to within a tolerance of $\pm$ 3 psi.

All containers equipped with bulk cushion suspensions shall show no sign of physical degradation as evidenced by loss of content restraint.

Deterioration, condensation, or change in performance tolerance limits of any internal or external component which could in any manner prevent the container from meeting operational requirements shall provide reason to consider the test specimen as having failed to withstand the effects of a high altitude unprotected transit environment.

## 4-7 RAIN TEST

The rain test is conducted to demonstrate the ability of the container to shield its contents when exposed to rain under service conditions.

Sealed containers which have satisfied the low pressure test may be considered to be resistant to rain penetration and will adequately protect their contents. Open and free-breathing containers must be subjected to the test and their ability to protect their contents in a rain environment demonstrated.

### 4-7.1 PROCEDURE

The container shall be placed in a rain chamber and positioned as it would be under transit and field storage conditions. The rate of rainfall, intensity, and duration are varied together with wind velocity. See MIL-STD-810, Method 506.1, for the detailed procedure. At the conclusion of the test period, the test item shall be removed from the test chamber and inspected.

### 4-7.2 CRITERIA FOR REJECTION

Lack of drainage ports and the inability of the container to purge itself of any rain penetration as evidenced by accumulation of water pockets, swelling, or other deterioration shall be cause for rejection.

## 4-8 SAND AND DUST TEST

The sand and dust test is conducted to determine the resistance of containers to blowing fine sand and dust particles. Because of their abrasive characters, sand and dust may affect items having moving parts. Hinges and latches may bind and protective finishes

may deteriorate when subjected to the sandblast effects of this environment. Dust particles may form nuclei for the condensation of moisture, thus introducing a source for corrosion. Air valves may malfunction due to clogging of intake ports and protective filters.

Quite often, one may circumvent the need to conduct this costly test entailing special test equipment by using only certified components and finishes. Many paints and protective finishes are certified as being sand resistant. The use of sealed bearings negates the need for testing. Commercially available valves which have been certified as functionally resistant to sand and dust can be used. In addition, the pressure test, if successful, provides sufficient evidence to qualify the container to resist the penetration of sand and dust. The procedure that follows is included to permit testing of either containers or their components in situations where the item or items have not been previously tested and certified.

### 4-8.1 PROCEDURE

The sand and dust characteristics used in this test are described in MIL-STD-810, Method 510.1. This compound is commercially known as "140-mesh silica flour".

The test item shall be placed in a test chamber equal to that specified in MIL-STD-810. The sand and dust concentrations are held constant, and the air velocity, temperature, and duration are varied. See MIL-STD-810, Method 510.1, for the detailed procedure.

At the end of this exposure period, the test item shall be removed from the test chamber and allowed to cool to room temperature. Accumulated dust shall be removed from the test item by brushing, wiping, or shaking—care being taken to avoid introduction of additional dust into the test item. Under no circumstances shall dust be removed by either air blast or vacuum cleaning.

### 4-8.2 CRITERIA FOR REJECTION

The container or component items subject to test shall be functionally operated and inspected. Pitting, flaking, or any damage to the protective finish affecting its protective qualities shall constitute a failure. Malfunction of functional components and/or penetration of sand and dust to within the confines of sealed containers shall be cause for rejection.

## 4-9 SALT FOG TEST

The salt fog test is conducted to determine the resistance of containers to the effects of a salt environment. Damage to be expected from exposure to salt fog is primarily corrosion of metals, although in some instances salt deposits may result in clogging or binding of moving parts.

The effects of salt fog exposure can be predicted and will permit the designer to circumvent this phase of the test program. The usefulness of conducting the salt fog test on the complete container is unrealistic; component parts and material samples can be tested separately.

Many materials and finishes are qualified as resistant to salt fog deterioration, and the electrolytic corrosion between dissimilar metals can be predicted. As such, the salt fog test is not often included and may be safely eliminated from the test plan by applying good design technique.

When this test is deemed necessary due to the introduction of new materials and/or technique, the procedure detailed in MIL-STD-810, Method 509.1, may be applied.

## 4-10 HUMIDITY TEST

The humidity test is conducted to determine the resistance of equipment to the effects of exposure to a warm, highly humid atmosphere such as is encountered in tropical areas. This is an exaggerated environmental test, accomplished by the continuous exposure of the equipment to high relative humidity at cyclic elevated temperatures. These conditions impose a vapor pressure on the equipment under test which constitutes the force behind the moisture migration and penetration. Corrosion is one of the principal effects of humidity.

Hygroscopic materials are sensitive to moisture and deteriorate rapidly under humid conditions. Absorption of moisture by many materials results in swelling which destroys their functional utility, and causes loss of physical strength and changes in other important mechanical and electrical properties.

*Sealed containers* having satisfactorily passed the low pressure test can be considered to be resistant to moisture penetration and consequently *need not be tested* unless the exterior finish is not impervious to this environment and qualification is considered necessary.

Containers equipped with *controlled-breathing* mechanisms and desiccants *must be subjected* to the humidity test to establish the effectiveness of these protective devices and to verify the amount of desiccant required.

*Free-breathing* containers offer no resistance to humidity penetration. If the outer shell and suspension materials are certified as moisture resistant, the *test need not be conducted.* It may be assumed that items housed in free-breathing containers are inherently protected or are inert to the effects of high humidity.

### 4-10.1 PROCEDURE

The test chamber and accessories shall be constructed and arranged in a manner to avoid condensate dropping on the equipment under test. The chamber shall be vented to the atmosphere to prevent the buildup of vapor pressure. Relative humidity shall be determined from the dry bulb-wet bulb thermometer comparison method. The wet bulb thermometer shall be installed at the internal mouth of the air inlet duct. The air velocity flowing across the wet bulb shall be not less than 900 ft/min. Provisions shall be made for controlling the flow of air throughout the internal test chamber area where the velocity of air shall not exceed 150 ft/min. Distilled or deionized water having a pH value between 6.0 and 7.2 at 73°F (23°C) shall be used to obtain the specified humidity. The details of the test procedure are described in MIL-STD-810, Method 507.1.

### 4-10.2 CRITERIA FOR REJECTION

Evidence of moisture penetration resulting in the accumulation of condensate within the interior of sealed containers shall be cause for rejection. Swelling or saturation of container components shall constitute a failure.

Any deterioration of the container or of any of its components shall reflect upon its ability to withstand the effects of a humid environment.

## 4-11 SUNSHINE TEST

The sunshine test is conducted to determine the effect of solar radiant energy on the container and its components. Exposure to sunshine will cause heating of equipment which may cause bending, differential expansion, melting, and binding; and photodegradation such as fading of fabric colors in addition to checking of paints, natural rubber, and plastics.

The sunshine test is applicable to any item of equipment which may be exposed to solar radiation during service or while in storage. Examples of container components which must be protected from or be inherently resistant to the deleterious effects of sunshine are:

a. Exterior finishes
b. Exposed seals and gaskets
c. Wooden skids
d. Plastics
e. Rubber bumpers and externally mounted elastomers
f. Web straps and tie-down devices
g. Decals and markings.

Those components housed within the container and not normally exposed to sunlight need not be resistant to solar radiation. In addition, many of the materials and finishes common to container construction are usually resistant to solar radiation and qualify for use by compliance with approved specifications. Consequently, the sunshine test is *not often included* in test programs unless the design introduces new and untested materials and/or finishes.

### 4-11.1 PROCEDURE

The test specimen shall be placed within the test chamber and exposed to radiant energy at the rate of $104 \pm 4$ W/ft$^2$.

Fifty to 72 W/ft$^2$ shall be in wavelengths above 780 nm, and 4 to 7 W/ft$^2$ shall be in wavelengths below 380 nm. The test chamber temperature shall be maintained at 120°F (49°C) for a period of not less than 48 h. The test item shall then be returned to room temperature and inspected. The details of the test procedure are described in MIL-STD-810, Method 505.1.

### 4-11.2 CRITERIA FOR REJECTION

Deterioration of any component which could in any manner contribute to or prevent the equipment from meeting functional, maintenance, and service requirements shall be cause for rejection.

## 4-12 FUNGOUS TEST

The fungous test is conducted to determine the resistance of containers to fungi. Fungi secrete enzymes which can destroy most organic substances and many of their derivatives. Organic acids—produced during metabolism—cause metal corrosion, glass etching, grease hardening, and other chemical and physical changes.

The majority of today's packaging materials are either inert to attack by enzymes or can be conveniently treated to resist fungous growth. *Consequently, containers are rarely subject to fungous test.*

In those instances where new materials or finishes are used and require qualification, the test procedure delineated in MIL-STD-810, Method 508.1, is applicable.

# CHAPTER 5
# MECHANICAL SUSPENSION SYSTEMS

*Types of mechanical suspension systems—together with their advantages and disadvantages—for rocket and missile containers are discussed. A detailed procedure is given, with examples, for the design of a helical spring suspension system.*

## 5-0 LIST OF SYMBOLS

$a$ = acceleration due to gravity, ft/s²
$a_0$ = impressed amplitude, in.
$a'$ = retarding acceleration, ft/s²
$B$ = clearance between each coil when spring is supporting a load, in.
$C$ = damping coefficient of shock absorber, lb•s/in.
$C_c$ = critical damping, lb•s/in.
$C_t$ = total system damping, lb•s/in.
$d$ = wire diameter, in.
$D$ = mean coil diameter, in.
$E_t$ = torsional modulus of elasticity or modulus of rigidity, lb/in²
$f$ = deflection per active coil for a given load, in.
$f_n$ = natural frequency, Hz
$F$ = mean force, lb
= frictional force, lb
$G_m$ = fragility factor, g-units
$h$ = flat-drop height, in.
$k$ = spring rate, lb/in.
$k_t$ = total spring rate, lb/in.
$K_w$ = Wahl factor, dimensionless
$L$ = free spring length, in.
$m$ = mass, lb•s²/ft (slug)
$n$ = number of active coils in spring, dimensionless
$N$ = normal force, lb
$p$ = pitch or lead of free or unloaded spring, in.
$P$ = load on spring, lb
$P_0$ = disturbing or imposed force, lb
$S$ = spring deflection, in.
$S_i$ = deflection due to impact load, in.
$S_s$ = deflection due to static load, in.
$S_t$ = total deflection, in.
$T_c$ = corrected shear stress, lb/in²
$T_r$ = corrected shear stress range, lb/in²
$TR$ = transmissibility, dimensionless
$V_t$ = velocity at impact, ft/s
$V_0$ = initial velocity, ft/s
$W$ = weight, lb
$X_0$ = amplitude at resonance, in.
$\mu$ = coefficient of friction, dimensionless
$\omega_n$ = natural frequency, rad/s

## 5-1 GENERAL

Mechanical suspension systems for rockets and missiles are grouped for convenience into three general categories:

a. Helical springs
b. Torsion bars
c. Other types of mechanical suspensions.

The first category, helical springs, will receive a more detailed analysis than the others because of its wider use and the greater amount of readily available source material defining its application and performance. The procedure to be followed in designing a spring suspension system will be given; equations, damping, and mathematical examples will be included.

*Torsion bar suspension systems are not recommended for rocket and missile component containers.* The designer should give serious consideration to the inherent problems of this type of suspension system before entering into its formal design and construction. Par. 5-3 gives a discussion of the problems associated with torsion bar suspension systems. The complexity of torsion bar calculations precludes their inclusion in this limited study. A description of the torsion bar system used in the Army CORPORAL M351 Missile Container is included only for general orientation.

The third category includes such suspension systems as cable isolators, Jarret-type springs, and single use energy dissipators. The brevity of par. 5-4.3 should not be interpreted as a condemnation of these suspension systems. Indeed, time and further development may prove one of these systems superior to elastomeric mounts or helical springs—the two topics covered in detail (Chapters 5 and 6).

## 5-2 HELICAL SPRINGS

Only round wire, helical compression or extension springs are considered in this paragraph (see Fig. 5-1). Equations found in *Machinery's Handbook* show

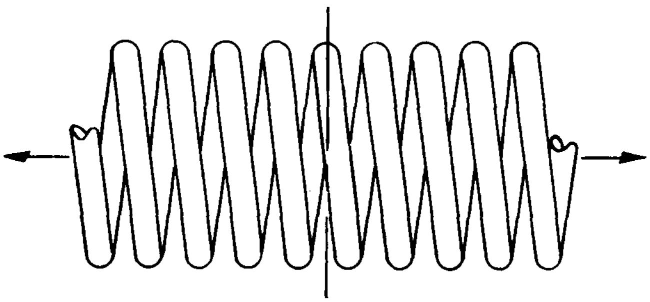


**Figure 5-1. Helical Spring**

that fiber stress for a given shock load will be greater in a spring made from a square bar than in one made from a round bar; the side of the square bar being equal to the diameter of the round bar. Accordingly, square wire springs should not be used.

Conical compression springs are used as a means of decreasing the solid height by telescoping action. Since this requirement will in all probability never arise in container design, conical springs have been excluded from this study.

Elliptical or leaf springs are not included because these types of uniaxial springs do not lend themselves to the triaxial deflections necessary in rocket and missile containers.

## 5-2.1 GENERAL DESIGN PROCEDURE

The design of a helical spring suspension system for rocket and missile containers includes the considerations that follow.

### 5-2.1.1 Loads and Required Deflections

The first and obvious step is to determine the weight, location of center of gravity, possible attachment points, and shipping attitude of the component or item to be contained.

From the fragility factor $G_m$ of the item, the minimum deflection and minimum time through which this deflection occurs can be determined (see Chapter 1).

It is interesting to note that when triaxial protection is provided to an item by its suspension system—assuming the item fragility factor equal in all directions—varying levels of protection exist. Therefore, varying deflections will be required in the three axes since the severity of the tests, which simulate the hazards to be encountered, often will vary in the three axes. For example, a container may be required to withstand a 30-in. end drop and a rollover test (see Chapter 4). This will result in a much larger shock input in the vertical direction than in the lateral direction. The suspension system therefore must provide a greater level of protection in the vertical direction.

Knowing the fragility factor $G_m$ and the tests required to simulate the hazards the container will encounter, the designer can determine the deflection and pulse time required of the suspension system in each of the three pertinent axes. See Chapter 1 for deflections, and Chapters 3 and 4 for hazards and tests.

### 5-2.1.2 Body Types and Spring Locations

The body type concept of the container must be established (see Chapter 8). Spring suspension systems can be designed for either top- or end-opening containers. The location of the springs cannot be divorced from and are interrelated to the configuration of the container. The springs should be located about the center of gravity of the packaged item such that each spring carries an equal load. If this arrangement is not possible, then the spring rate should be adjusted to compensate for the unequal loading. Figs. 5-2 and 5-3 illustrate several containers with spring suspension systems.

The spring(s) necessary to satisfy the application requirements can be designed once the body type and its configuration, the number and location of the spring(s), and the deflection they must provide have been established.

### 5-2.1.3 Calculation of Spring Rate

One of the first steps in designing a spring is the calculation of the spring rate $k$. The spring rate, sometimes called stiffness, is the force required to produce unit deflection. The units of $k$ are pounds per in. $k$ can be found from the following equations:

a. For *slowly* applied loads:

$$k = \frac{P}{S_t} = \frac{E_t d^4}{8D^3 n}\text{, lb/in.} \qquad (5\text{-}1)$$

b. For *suddenly* applied loads:

$$k = \frac{2P}{S_t} = \frac{E_t d^4}{4D^3 n}\text{, lb/in.} \qquad (5\text{-}2)$$

where

$k$ = spring rate, lb/in.
$P$ = load on spring, lb
$S_t$ = total spring deflection, in.
$d$ = wire diameter, in.
$D$ = mean coil diameter, i.e., (outside dia of spring) − (wire dia), in.
$n$ = number of active coils in the spring, dimensionless
$E_t$ = torsional modulus of elasticity or modulus of rigidity, lb/in$^2$

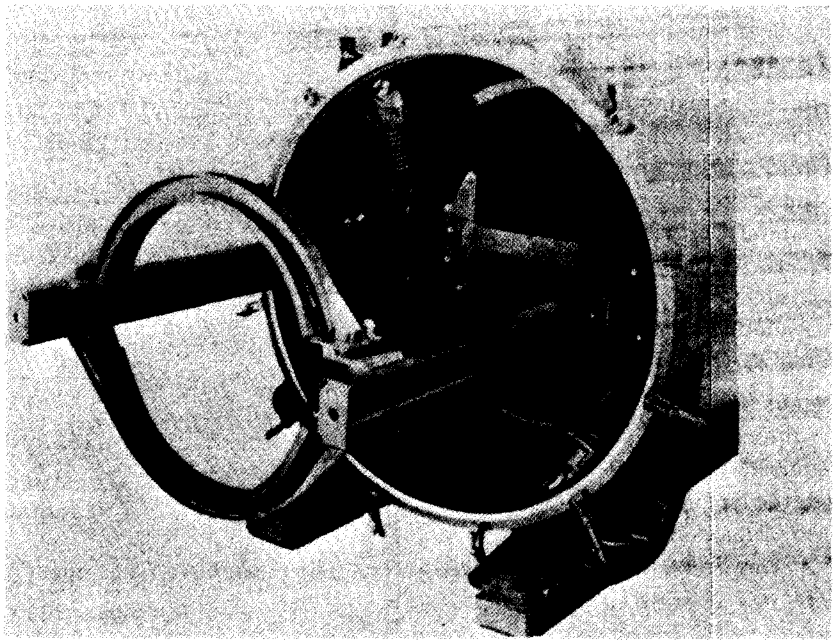


Figure 5-2. End View of NIKE-HERCULES Container Showing Spring Suspension System and Roll-out Mechanism (Damping is provided by tubular-type shock absorbers mounted inside the coil springs.)

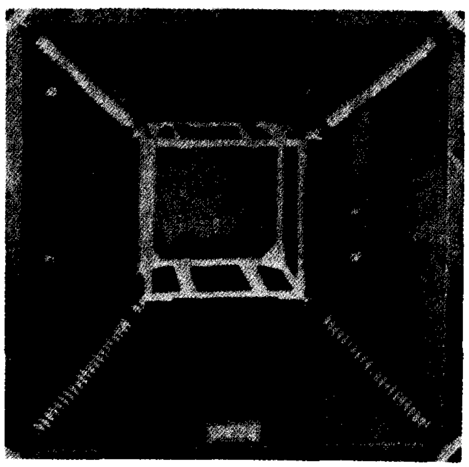


Figure 5-3. Three-Dimensional Protection Provided to Missile Component by Helical Springs With Stainless Steel Spring Cushions Inside the Springs Used for Damping (Spring rate is identical in all planes, assuring equal performance regardless of the attitude at the time of impact.)

The spring rate can be found knowing the load $P$, and deflection $S_t$, or the spring dimensions $d$, $D$, $n$, and $E_t$. However, since the spring rate is used to determine the spring dimensions, the procedure following will be to first find $k$ using known $P$ and $S$, and then to determine the spring dimensions. The deflection $S_t$ that the spring must provide is dictated by the fragility factor $G_m$ and the container qualification tests required. The deflection, load $P$, and the resulting spring rate can be found as shown in the illustrative problem that follows (see Fig. 5-4).

*Given:* Item weight $W = 1000$ lb
Item fragility factor $G_m = 20$
Test required, $h$ = 30-in. flat drop.

*Object*: To find the spring rate $k$ required for adequate protection.

If the container is dropped 30 in., it attains a velocity $V_t$ at impact of

$$V_t = \sqrt{V_0^2 \pm 2ah} \tag{5-3}$$

where

$V_t$ = velocity at impact, ft/s
$V_0$ = initial velocity, ft/s
$h$ = drop height, ft
$a$ = 32.0 ft/s², acceleration due to gravity.

Substituting into Eq. 5-3, using the positive (+) sign because the acceleration is increasing and $V_0$ = 0 since the body is initially at rest, we find

$$V_t = \sqrt{0 + 2(32)(30)/12}$$

$$V_t = \sqrt{160}$$

$$V_t = 12.65, \text{ ft/s.}$$

Both the container and the item will have a velocity of 12.65 ft/s at impact.

With the fragility factor $G_m$ = 20 and the 30-in. drop height, enter Table 1-4. The table for linear systems is used because an undamped spring is essentially linear, i.e., the spring rate is constant throughout the range of its use. The required deflection is found to be 3.3 in. Therefore, the item which is moving at 12.65 ft/s at impact must be brought to rest in a distance of 3.3 in. in order to prevent damage to the item.

Now:

$$h = 3.3 \text{ in.} = 3.3/12 \text{ ft}$$

$V_t$ = final velocity = 0 ft/s because the item will come to rest
$V_0$ = initial velocity, i.e., the velocity of the item as the container strikes the ground, = 12.65 ft/s

and let

$a'$ = unknown retarding acceleration in ft/s².

*Note:* Assume that the container and the ground are rigid.

Eq. 5-3 can be used to calculate the retarding acceleration that must be provided by the springs. Here the negative (−) sign is used because the acceleration is decreasing.

$$V_t^2 = V_0^2 - 2a'h$$

$$a' = \frac{V_0^2 - V_t^2}{2h}$$

$$= \frac{(12.65)^2 - 0}{2(3.3/12)}$$

$$= 290.9 \text{ ft/s}^2.$$

The mean force $F$ at impact follows Newton's Law

$$F = ma = (W/g)a, \text{ lb} \tag{5-4}$$

where

$m$ = mass of the item, lb•s²/ft, i.e., slug
$W$ = weight of item, lb
$g$ = acceleration due to gravity = 32 ft/s²
$a$ = acceleration of item, ft/s²

Therefore,

$$F = (1000/32)290.9$$

$$F = 9091 \text{ lb.}$$

This force will be used in finding the spring rate and also the stresses developed in the spring.

The time $t$ through which the deceleration takes place is:

$$t = V_t/a' \tag{5-5}$$

$$t = 12.65/290.9$$

$$= 0.0435$$

$$s = 43.5 \text{ ms.}$$

Having determined deflection $S$ and the force $F$, we now use Eq. 5-2 to calculate the total spring rate $k_t$.

$$k_t = 2F/S_t$$

$$= (2)(9091)/3.3$$

$$= 5510 \text{ lb/in.}$$

When springs are placed in parallel, the total spring rate is the sum of the individual spring rates (see Fig. 5-5).

$$k_t = k_1 + k_2 + \cdots + k_n. \tag{5-6}$$

If $k_t$ = 5510 lb/in. and four identical springs each carrying an equal weight are used, then

$$k_t = 4k \tag{5-7}$$

$$k_t/4 = 5510/4 \text{ lb/in.}$$

$$= 1378 \text{ lb/in.}$$

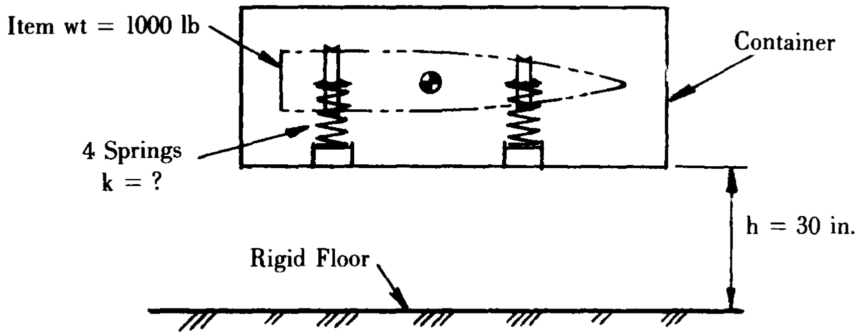



**Figure 5-4. Example of Spring Suspension System Using 4 Parallel Springs**

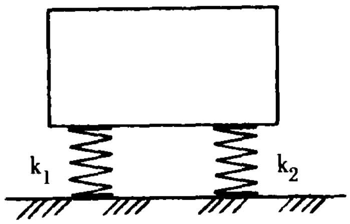



**Figure 5-5. Springs in Parallel**

Each of the four springs must then have a spring rate of 1378 lb/in.

An alternate and less complex method for arriving at the spring rate in the example problem can be found in *Dynamics of Package Cushioning*, by Mindlin. This solution is given by Eq. 5-8.

$$k_t = 2hW/S_t^2 \qquad (5\text{-}8)$$

where the terms are the same as those previously defined.

Therefore,

$$k_t = (2)(30)(1000)/(3.3)^2$$
$$= 5510 \text{ lb/in.}$$

Division by 4 gives the same spring rate $k$ of 1378 lb/in.

Eq. 5-8 can be used for cushioning with a linear load-displacement relation and suddenly applied load. When the load is slowly applied, Eq. 5-9 applies.

$$k = hW/S_t^2. \qquad (5\text{-}9)$$

### 5-2.1.4 Calculation of Total Deflection

When calculating the deflection of springs used in containers, it should be noted that the springs undergo a static loading due to the weight of the item upon which is superimposed a dynamic load resulting from shock and/or vibration.

The total deflection of the springs must be found in order to calculate the physical dimensions of the springs. The total deflection $S_t$ will be the deflection due to impact plus that resulting from the static load:

$$S_t = S_i + S_s \qquad (5\text{-}10)$$

where

$S_i$ = deflection due to impact load, in.
$S_s$ = deflection due to static load, in.

Continuing with the example problem, we find

$$S_t = S_i + S_s = 3.3 + P/k$$

where $P$ equals the load carried by each spring, i.e., 1000/4 = 250.

$$S_t = 3.3 + 250/1378$$
$$= 3.3 + 0.18 = 3.48 \text{ in.}$$

### 5-2.1.5 Vibration and Damping

In the preceding paragraphs the spring rate and spring deflections have been found. These values will have a direct bearing on the vibrational response of the suspension system and the forces transmitted to the item.

A container in transit will undergo forced vibrations. The vibrational response of the suspension system must be determined in order to exclude the possibility of (1) excessive and damaging oscillations at resonance, and (2) the failure of the springs due to fatigue.

A spring contains virtually no internal damping; therefore, in order to reduce excessive displacements at resonance to a tolerable level, several damping methods are employed, namely:

a. Dry or coulomb friction—between rigid bodies
b. Fluid friction—a rigid body moving in a fluid
c. Internal friction—between the molecules of seemingly inelastic bodies.

In the first two types of damping, the frictional force developed is directly proportional to the speed of the moving body. The coulomb-type shock ab-

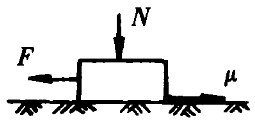



**Figure 5-6. Forces on a Body in Motion**

sorber, illustrated in Figs. 5-7 and 5-8, follows Eq. 5-11 (see Fig. 5-6).

$$F = \mu N, \text{ lb} \tag{5-11}$$

where

$F$ = frictional force, lb
$N$ = normal force, lb
$\mu$ = coefficient of friction, dimensionless.

A shock absorber operating on the fluid friction principle is the automotive tubular-type shock absorber. This absorber is available in a wide variety of sizes, capacities, and end configurations. The fluids normally used in this type of shock absorber tend to stiffen at −65°F. Therefore, if such operating temperatures are anticipated, a silicone oil or comparable fluid should be specified to prevent the loss of performance. The amount of damping for a given shock absorber can be obtained from its manufacturer.

Stainless steel wire mesh has also been used successfully to dampen unwanted vibrations. The claimed advantages of this type of damping when used in conjunction with metal springs is that it provides an all metal mount virtually impervious to temperature, oil, water, ice, ozone, fungus, etc. Figs. 5-9 and 5-10 illustrate this type of mount.

The spring rate and deflection found in pars. 5-2.1.3 and 5-2.1.4 will be used in an illustrative example in par. 5-2.1.6 to show the calculations which must be performed in order to determine the vibratory response of a suspension system.

#### 5-2.1.6 Vibration and Damping Coefficients

Use the example given in par. 5-2.1.2.2 with the addition of four tubular-type shock absorbers (see Fig. 5-11).

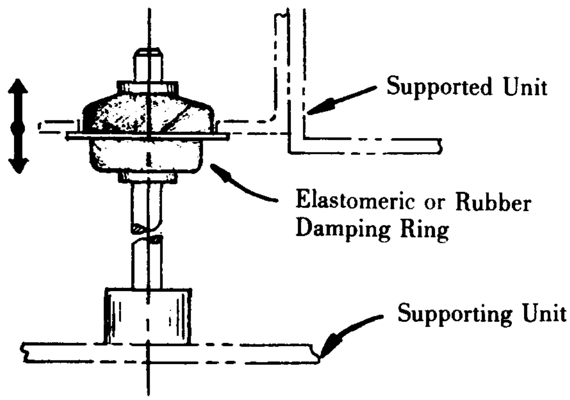
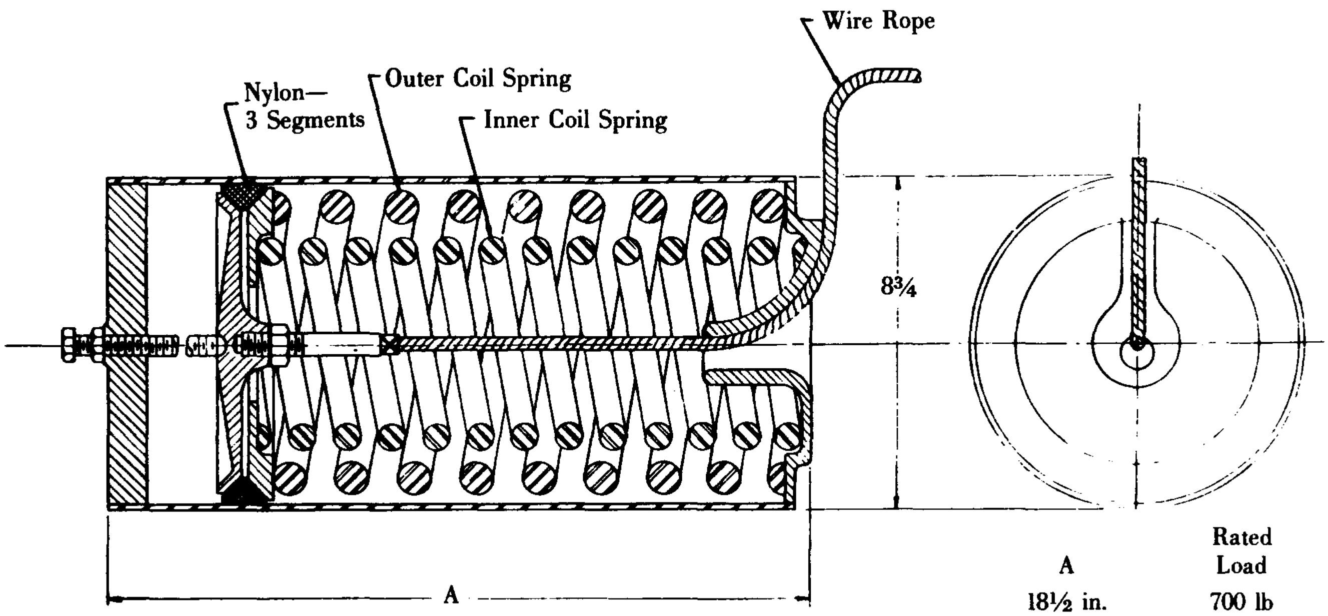



**Figure 5-8. Friction Damper Assembly**




| A | Rated Load |
|---|---|
| 18½ in. | 700 lb |
| 17¾ in. | 500 lb |
| 24 in. | 200 lb |

**Figure 5-7. Metal Shock Mount Using Friction Damping**

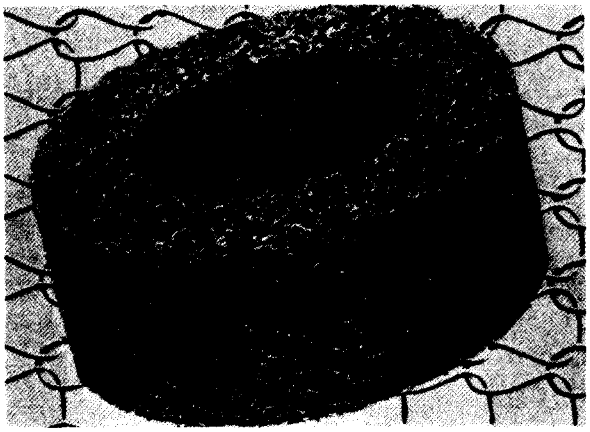


Figure 5-9. Typical Resilient Wire Mesh Cushion

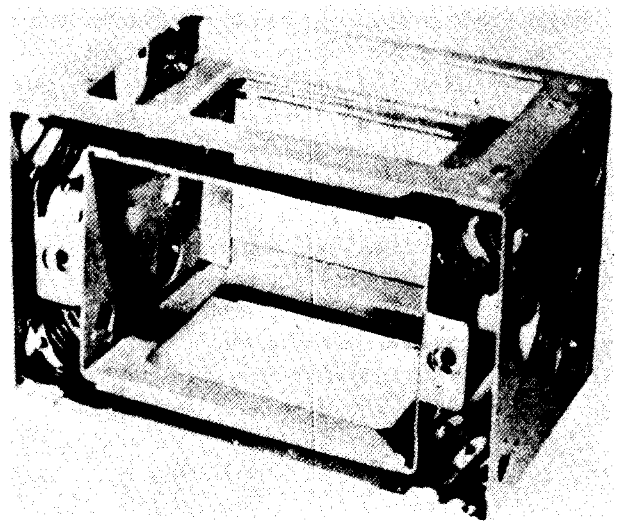


Figure 5-10. Mounting System Using Springs With Wire Mesh Damping

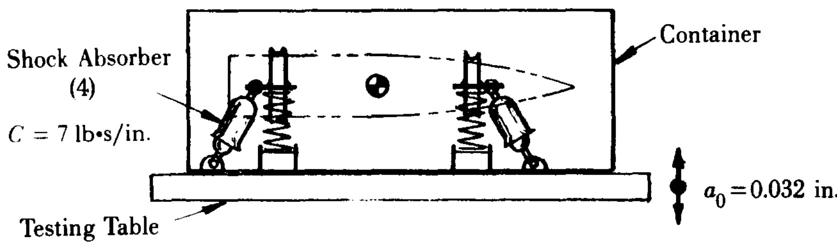



**Figure 5-11. Shock Absorption System for Coil Springs**

*Given:* Item weight W = 1000 lb
Static deflection $S_s = 0.18$ in.
Acceleration due to gravity $g = 386$ in./s$^2$
Damping coefficient of shock absorber
$C = 7$ lb•s/in.
Impressed amplitude $a_0 = 0.032$ in. (This value can be determined for any given condition from Chapters 3 and 4.)

*Object:* To find:
Natural frequencies $\omega_n$ and $f_n$
Disturbing or impressed force $P_0$
Amplitude $X_0$ at resonance
Transmissibility $TR$
Percent of critical damping.

The natural frequency $f_n$ of the system is:

$$f_n = \omega_n/(2\pi), \text{ Hz} \quad (5\text{-}12)$$

where

$\omega_n$ = natural frequency, rad/s.

For springs

$$\omega_n = \sqrt{g/S_s} \quad (5\text{-}13)$$
$$= \sqrt{386/0.18}$$
$$= 46.3 \text{ rad/s}$$

and by Eq. 5-12

$$f_n = 46.3/(2\pi)$$
$$= 7.37 \text{ Hz.}$$

The natural frequency of a suspension system is calculated to determine whether it coincides with the natural frequency of the transportation medium to which it is subjected. Chapters 3 and 4 provide guidance on the magnitude of the imposed vibrational frequencies for the pertinent modes of transportation. Generally the natural frequency of container suspension systems should be above 7 Hz. The natural frequency of 7.37 Hz calculated in the example is some-

what low; this value can be raised by decreasing the static deflection of the springs. However, this will increase the stiffness of the springs; therefore, care must be taken not to compromise the protection provided by the system when increasing the natural frequency of the spring.

Excessive vibrations can be reduced by increasing the damping. It should be noted that damping will not affect the magnitude of the natural frequency because, for spring suspension systems, the natural frequency is dependent solely on the static deflection. As a result, the natural frequency is calculated without taking into account the effects of damping.

The disturbing force $P_0$ for spring suspension systems at resonance is derived by Hartog as:

$$P_0 = \sqrt{(ka_0)^2 + (C_t a_0 \omega_n)^2} \quad (5\text{-}14)$$

where

$k$ = spring constant of complete system $= W/S_s$

$k = 1000/0.18 = 5556$ lb/in.

$a_0$ = impressed amplitude = 0.032 in.

$C_t$ = total damping of the system = $4C$ = (4)(7) lb•s/in.

$\omega_n$ = natural frequency = 46.3 rad/s.

Therefore, the disturbing force is:

$$\begin{aligned} P_0 &= \sqrt{[(5556)(0.032)]^2 + [(28)(0.032)(46.3)]^2} \\ &= 182.6 \text{ lb.} \end{aligned}$$

The amplitude $X_0$ of the system at resonance can now be found:

$$\begin{aligned} X_0 &= P_0/(C_t\omega_n) \quad (5\text{-}15) \\ &= 182.6/[(28)(46.3)] \\ &= 0.14 \text{ in.} \end{aligned}$$

The transmissibility $TR$ is the ratio of the disturbing force amplitude to the impressed force amplitude, i.e.,

$$\begin{aligned} TR &= X_0/a_0 \quad (5\text{-}16) \\ &= 0.14/0.032 = 4.38. \end{aligned}$$

The critical damping $C_c$ is

$$\begin{aligned} C_c &= 2k/\omega_n \quad (5\text{-}17) \\ &= (2)(5556)/46.2 \\ &= 240.5 \text{ lb•s/in.} \end{aligned}$$

Percent of critical damping is:

$$\begin{aligned} \%\,C_c &= (C_t/C_c)100 \\ &= (28)(100)/240 \\ &= 11.6. \end{aligned}$$

This value is somewhat low; it can be raised by increasing the damping or changing the spring rate. In container applications, a damping of 15 to 20% of critical damping at resonance is desired in order to prevent excessive oscillations. Fig. 5-12 illustrates various degrees of damping; the damped vibration curve being the desired condition. The shaded curve in Fig. 5-13 shows the results of the proper percentage of critical damping.

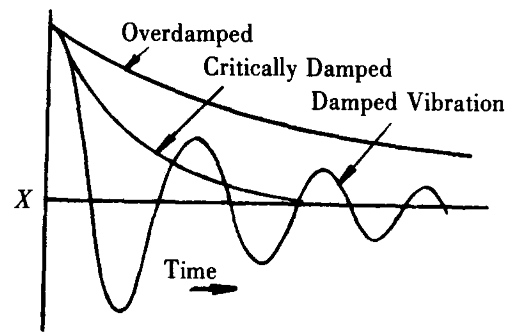



**Figure 5-12. Degrees of Damping**

In the preceding paragraphs the performance requirements of the spring suspension system have been calculated. First the spring rate was calculated using the impact or shock loading involved; then the effects of vibration were considered. There remains the determination of the dimensions of the spring(s). This will require the choice of a material and the calculation of the stresses developed in the spring(s)— determined in par. 5-2.1.7.

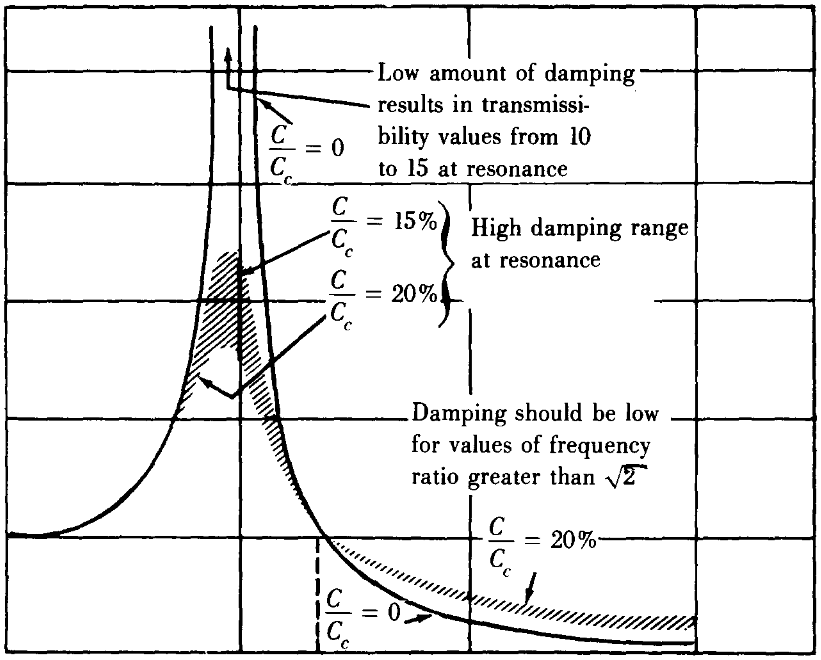
### 5-2.1.7 Spring Design

#### 5-2.1.7.1 General

For the complete treatment of spring design refer to authoritative texts such as Wahl, *Mechanical Springs*, and MIL-STD-29. The scope of this handbook permits only an outline of the many factors involved in the design of helical springs.

#### 5-2.1.7.2 Fatigue

A container in transit will be subjected to vibrations which will continually deflect its suspension




$$\text{Frequency Ratio} = \frac{\text{Forcing Frequency}}{\text{Undamped Natural Frequency}}$$

**Figure 5-13. Mounting Systems Possessing 15-20% of Critical Damping at Resonance are Desirable (This value should not be affected by any operating environmental changes such as pressure, temperature, or humidity. To reduce the transmissibility to a minimum, the damping ratio should decrease in value for a frequency ratio greater than $\sqrt{2}$.)**

system. When springs are subject to fatigue, the allowable stress in their design should be based on the endurance limit. This is the highest stress, or range of stress, that can be repeated indefinitely without failure of the spring. Ten million cycles of deflection generally are accepted as an infinite life. Definitions of severity of service are:

a. Light Service. Includes springs subjected only to static loads, having small deflections with low stress ranges. Subject to less than 1000 and seldom more than 10,000 deflection cycles in a lifetime.

b. Average Service. Subject to average use without shock loading. Subject to one hundred thousand to one million deflection cycles in a lifetime.

c. Severe Service. Subject to rapid deflections over long periods of time. Subject to one million to ten million deflection cycles in a lifetime. When designing springs for severe service, the endurance limit should be used in the calculation of stress.

Safe working stresses will differ for each material; these stress values should be obtained from the manufacturer of the material or from a reliable text.

Fatigue in conjunction with even slight corrosion is very effective in causing failure under comparatively small stresses. For example, spring steels subjected to stresses while in contact with fresh water fail at a stress range only 1/4 to 1/9 the normal endurance limit. The reason for such premature failure is that, in a spring, the torsional fiber stress is a maximum at the surface of the wire. Any surface defect accelerates the start of a crack which then continues through the wire, causing complete failure.

Fatigue failures can be reduced by improving the spring surface and by preventing corrosion of this surface. Shot-peening, which consists of propelling

steel shot at high velocity against the spring surface, will improve this surface. This process tends to increase the endurance strength by (1) cold working the surface where the stress is highest, and (2) prestressing the surface layer under compression. Since fatigue failures are due to tension stresses, superimposing compressive stresses where tension stresses occur enables the spring to carry a greater load.

Steel springs can be protected from corrosion by plating; however, the endurance limit will be reduced. Painting was found to be unsatisfactory for container springs. It is recommended that a thermally fused epoxy plastic coating be applied to steel springs to prevent corrosion. This process was used with success on NIKE HERCULES containers. (See Rock Island Arsenal Purchase Description RIAPD-636, *Coating Protective, Thermally Fused Epoxy Plastic.*)

#### 5-2.1.7.3 Temperature

Most common spring materials will perform satisfactorily at −65°F under static loads; however, problems often arise with the ability of a material to absorb impact loads at −65°F. Many materials become brittle at low temperatures, with carbon steels showing a dramatic loss of impact strength at even moderately low temperatures (0°F). Nickel alloys will show little loss of impact strength at −65°F.

For compression and extension springs subjected to shear loads and stresses, the stress calculations will be based on the torsional properties of the material. The torsional modulus of elasticity $E_t$, a factor in determining the relation between the load and deflection of a spring, will vary with temperature. As $E_t$ increases, so does the spring stiffness. This variation is shown in Table 5-1 for several spring materials.

After the material has been selected, using the information calculated in previous paragraphs, the physical dimensions of the spring can be determined.

#### 5-2.1.7.4 Spring Dimensions

The procedure followed in determining the spring dimensions is one of trial and error. An example, using the deflections and loads found in previous paragraphs, will illustrate this procedure. Choosing a material and a convenient outside diameter, and estimating the wire diameter, we will determine the free length of the spring required.

*Given:* Total deflection $S_t = 3.48$ in.
Total load (includes impact and static load on one spring) $P = 2523$ lb.

*Select:* Material: chrome vanadium steel with
$E_t = 11.5 \times 10^6$ psi
Outside coil diameter = 4 in.
Wire diameter $d = 0.625$ in.
$\therefore$ Mean coil diameter $D = 4 - 0.625 = 3.375$ in.

*To Find:* Number of active coils $n$, pitch $p$, and free length $L$.

The following equations will be used to solve this problem:

$$n = S_t E_t d^4/(8PD^3) \tag{5-18}$$

$$p = B + f + d \tag{5-19}$$

$$L = np + 2d. \tag{5-20}$$

Solve for $n$, using Eq. 5-18.

$$n = (3.48)(11.5 \times 10^6)\,(0.625)^4/[(8)(2523)(3.375)^3]$$
$$= 7.87.$$

Therefore, the number of active coils is $n = 7.87$. Solve for $p$, using Eq. 5-19.

$$p = B + f + d$$

where

$p$ = pitch or lead of free or unloaded spring, in.
$B$ = clearance space between each coil when spring is supporting some load $P$, in. (Calculate $B$ by using 25% of the deflection per active coil.)
$f$ = deflection per active coil for a given load $P$, in.
$d$ = wire diameter, in.

Therefore,

$$p = (0.25)(3.48)/7.87 + 3.48/7.87 + 0.625$$
$$= 1.18 \text{ in.}$$

Solve for spring length $L$, using Eq. 5-20. This equation is for springs with squared and ground ends. For springs with other type ends, consult a reliable text on spring design.

$$L = (7.87)(1.18) + (2)(0.625)$$
$$= 10.54 \text{ in.}$$

These calculations provide a tentative spring design. If it does not fit the available space, a new design can be found by choosing different values of wire diameter, outside diameter, material, etc. When a suitable size spring is found, the stresses developed from impact and fatigue loading must be checked.

The methods used for finding loading due to impact and fatigue have been indicated in the preceding paragraphs. Equations used for finding the stresses developed in springs follow in par 5-2.1.7.5.

**TABLE 5-1**
**VARIATION OF TORSIONAL MODULUS OF ELASTICITY $E_t$ WITH TEMPERATURE**

| Material | Temperature at −100°F, psi | at 0°F, psi | at +200°F, psi |
|---|---|---|---|
| Hard Drawn Steel | 11,550,000 | 11,200,000 | 11,240,000 |
| Si-Mn Steel | 11,450,000 | 11,200,000 | 10,600,000 |
| Chrome Vanadium Steel | 11,400,000 | 11,250,000 | 10,600,000 |
| Stainless Steel (18/8) | 10,100,000 | 10,300,000 | 9,750,000 |
| Monel | 9,100,000 | 9,100,000 | 9,050,000 |

#### 5-2.1.7.5 Calculation of Stresses

The following equations are used to find the stresses induced by impact and fatigue loading:

$$T_c = \frac{8PDK_w}{\pi d^3} = \frac{fE_t dK_w}{\pi D^2 n} \quad (5\text{-}21)$$

$$K_w = (4C-1)/(4C-4) + 0.615/C \quad (5\text{-}22)$$

$$C = D/d \quad (5\text{-}23)$$

where

$P$ = load on spring, lb
$D$ = mean coil diameter, i.e., (outside dia) − (wire dia), in.
$d$ = wire diameter, in.
$K_w$ = Wahl factor—correction factor for curvature, dimensionless
$n$ = number of active coils in spring, dimensionless
$C$ = spring index, dimensionless
$T_c$ = corrected shear stress, lb/in$^2$
$f$ = deflection per active coil for a given load, in.
$E_t$ = torsional modulus of elasticity or modulus of rigidity, lb/in$^2$

With fatigue loading and a cyclic load variation between $P_{max}$ and $P_{min}$, the corrected shear stress range $T_r$ can be calculated:

$$T_r = K_w 8 \left[\frac{(P_{max} - P_{min})D}{d^3}\right], \text{lb/in}^2 \quad (5\text{-}24)$$

When designing for −65°F and severe impact and fatigue loading, spring design calculations consider lower stresses than would be used at 70°F. Studies have indicated that a 25 to 30% reduction in published values for allowable stress, when designing steel springs, would be a reasonable figure to use under these conditions.

Where allowable stress values are given for statically loaded springs at 70°F, the following allowances can be made:

a. Compression springs that are preset and shot-peened, increase values 10 to 15%

b. For extension springs, reduce values 10 to 20%

c. For suddenly applied loads, reduce values by 50%.

The springs should also be checked for stresses developed at solid compression, eccentric loading, buckling, lateral loading, spring index, effects of vibrations, and resonance.

These calculations are a simplification of the actual forces a container will undergo. The base-mounted system illustrated in Fig. 5-11 represents the least complex application. However, troublesome coupled response can result because the center of gravity is above the elastic center of the mounting system. Further calculations are necessary to describe the motions of this system fully.

The advantages and disadvantages of spring suspension systems for rocket and missile containers are listed in Table 5-2.

Spring suspension systems should be considered for:

a. Items having considerable weight, 250 lb and greater

b. Items having low fragility factor, i.e., $10 \leq G_m \leq 20$ $g$'s, regardless of weight

c. Items requiring chemically inert suspension systems

d. Items requiring a high degree of triaxial protection. It is recommended that tension spring packages be used in such cases. See Fig. 5-3 for photo, and *Dynamics of Package Cushioning*, by Mindlin, for a description of the required calculations.

**TABLE 5-2**
**ADVANTAGES AND DISADVANTAGES OF SPRING SUSPENSION SYSTEMS**

| ADVANTAGES | DISADVANTAGES |
|---|---|
| Reliable | Requires damping |
| Not adversely affected by: | Possible large amplitudes when passing through resonance |
| Temperature, Oil, Water, Chemicals, Aging | Frequency of suspension system difficult to determine at right angles to springs |
| | Linear spring deflection rate |
| Isolates low frequencies better than rubber | |
| Does not drift | |
| Capable of providing identical protection in all directions | |

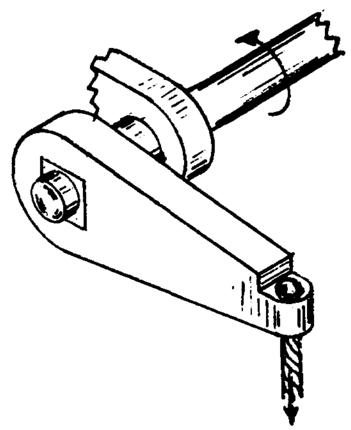
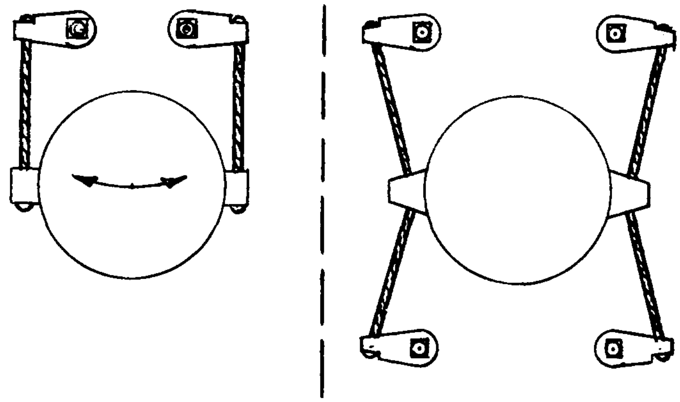


Figure 5-14. Torsion Bar-Cable



(A) Small Lateral Input, Large Amount of Displacement

(B) Restricted in Three Directions

Figure 5-15. Typical Torsion Bar-Cable Arrangement

## 5-3 TORSION BARS

Torsion bar springs have found a wide number of uses in recent years; however, they are not recommended for missile container suspension systems for numerous reasons. A torsion bar is essentially a uniaxial spring; therefore, in order for it to provide the triaxial protection required in container designs, the packaged item must be suspended from the torsion bar lever arms by cables or some other similar system (see Fig. 5-14).

To restrain the item properly, four or more torsion bars generally are required (see Fig. 5-15).

The arrangement illustrated in Fig. 5-15(A) does not easily lend itself to a top-opening container which is the preferred type of opening, except for very small or very large containers (see Chapter 8). If an end-opening container is chosen, the item cannot be removed quickly.

Although a torsion bar is an efficient energy-storing device, it is an expensive one. It is also a potentially dangerous one should the bar break during presetting; therefore, proper safeguards must be provided for personnel.

No calculations for a torsion bar suspension system are given because of their complexity and limited application. See *Design and Manufacture of Torsion Bar Springs* by the S.A.E. for guidance in the design of torsion bars.

In spite of disadvantages, a torsion bar suspension system was used with success on the CORPORAL M351 Missile Body Container. The extreme size of the missile and the state of the art of suspension systems at its time of design made this system a logical

choice. Figs. 5-16 through 5-21 illustrate the M351 container and its suspension system.

There are eight cables attached to the missile which lead from eight torsion bars in cylinders located on the exterior of the container. Each torsion bar is twisted initially 40 to 60 deg to provide a preload in excess of 30,000 in.•lb. Although this system performed well, it was difficult to connect the cables to the missile inside the container, especially at the closed end where it is necessary to work through access holes.

## 5-4 OTHER TYPES OF MECHANICAL SUSPENSION SYSTEMS

### 5-4.1 CABLE ISOLATORS

Another type of suspension system is one employing stranded steel cable interlaced between two metal retainer strips. One end of the assembly is attached to the item and the other to the supporting structure. An assembled pair of these isolators will provide triaxial shock and vibration protection to the item.

Suspension systems commonly include four cable isolator-assemblies which can be attached to the item

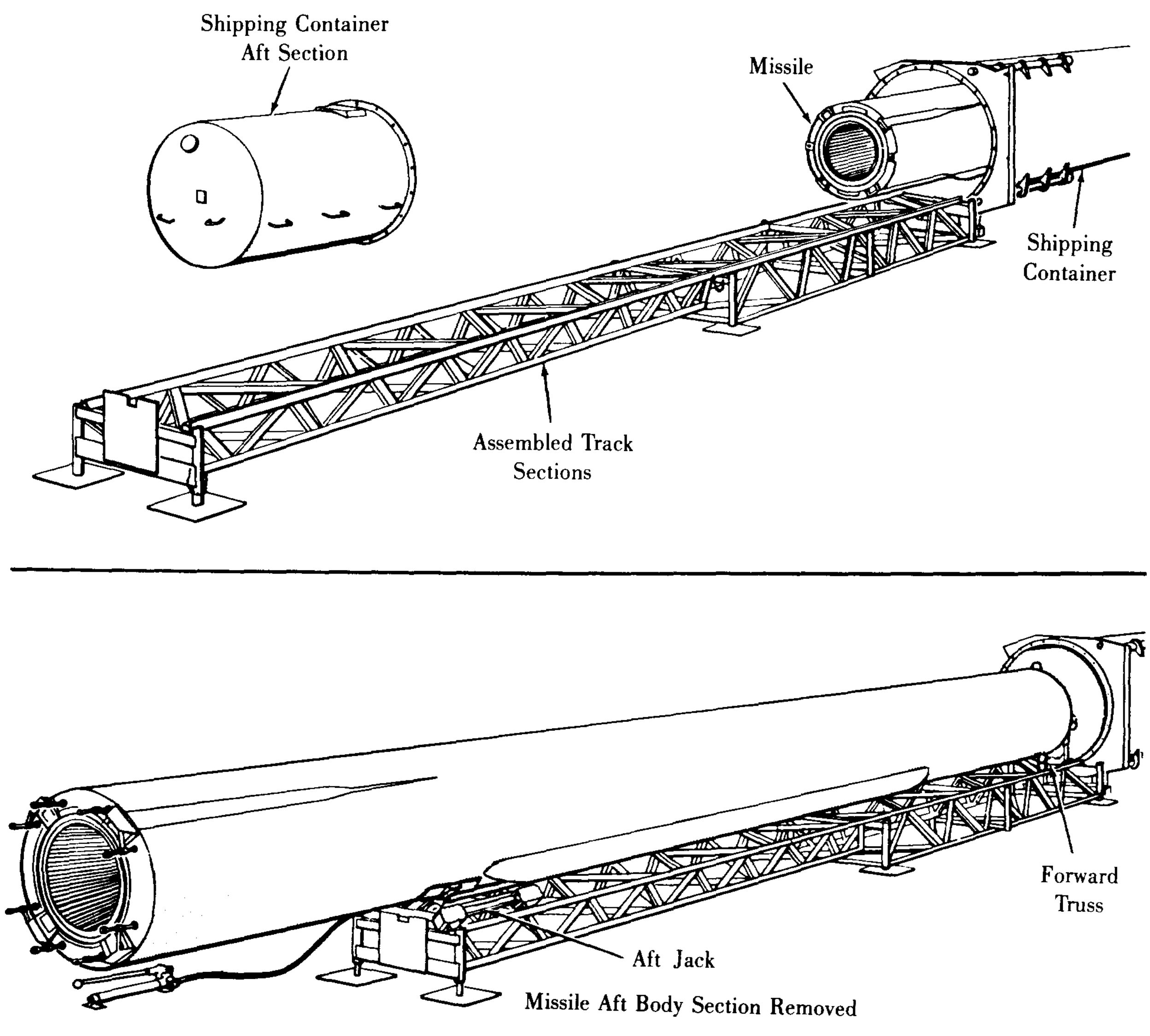



**Figure 5-16. CORPORAL Container Track Sections**

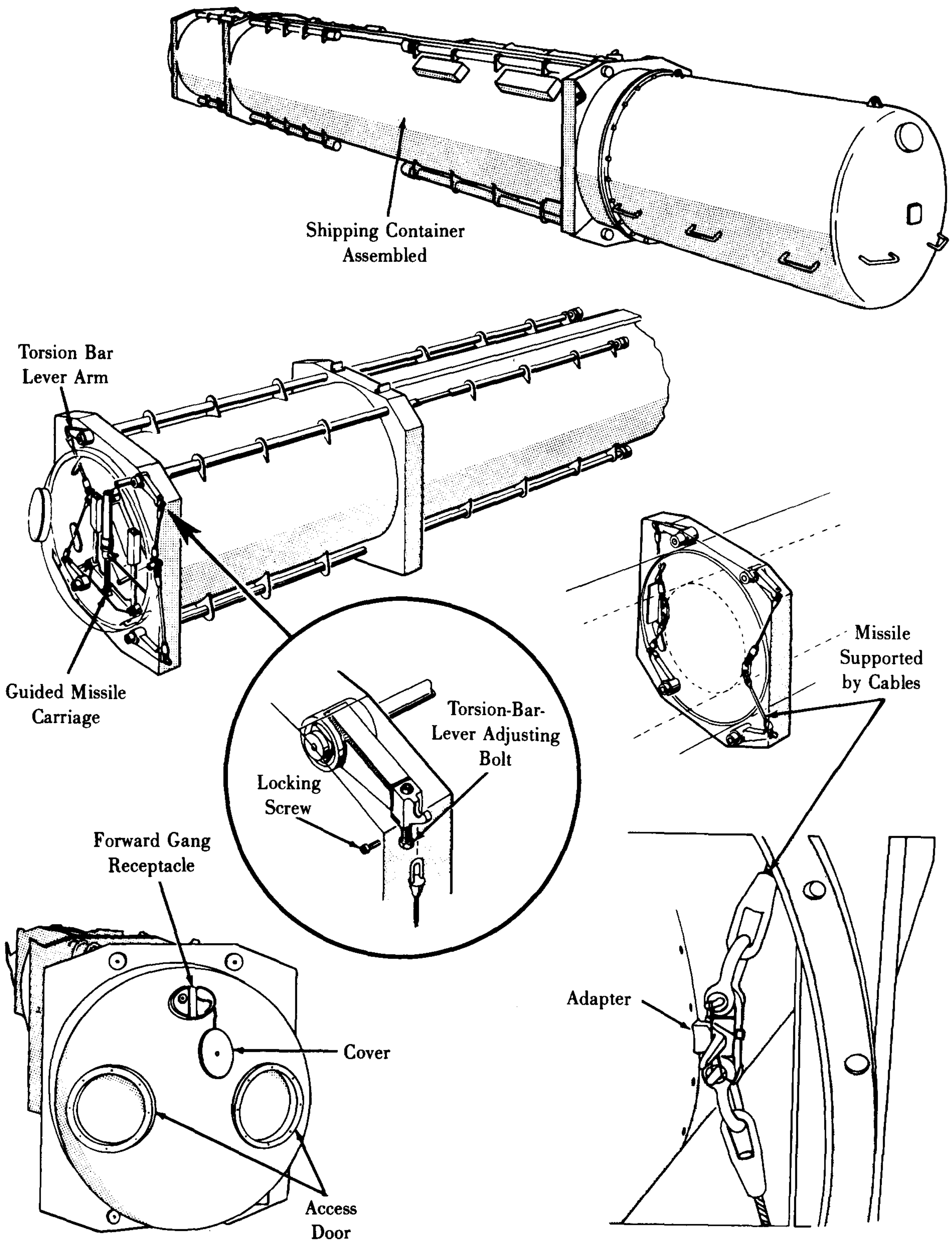



**Figure 5-17. CORPORAL Missile Shipping Container—Partially Exploded View**

at the corners, sides, top, or bottom in order to provide equal isolation in all directions. Fig. 5-22 illustrates some typical cable isolator systems.

Cable isolators can provide shock and vibration protection in all directions with an equal spring rate that can be easily varied. The spring rate is nonlinear. The natural frequency, which is normally in the 15- to 20-Hz range, can also be shifted easily.

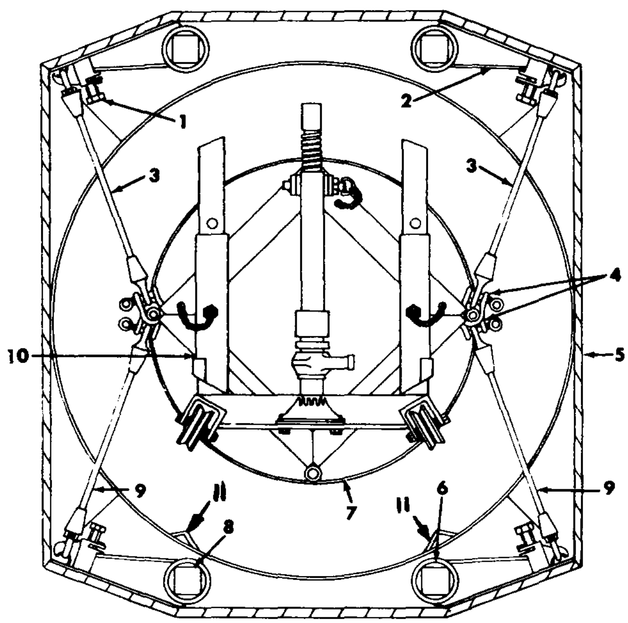
### 5-4.2 SINGLE USE ENERGY DISSIPATORS

Single-shot, sheet-type energy dissipators having mechanical properties similar to those of paper honeycomb find their use in the control of accelerations during an air drop impact. This type of suspension system is not recommended where repeated shock loads must be attenuated.

A complete dissertation on this subject will be found in *Design of Cushioning Systems for Air Drop*, by Maurice P. Gionfriddo, published by Quartermaster Research and Engineering Command, US Army, Natick, MA, October 1961. Because of the thoroughness of Mr. Gionfriddo's study, this subject will not be discussed further.

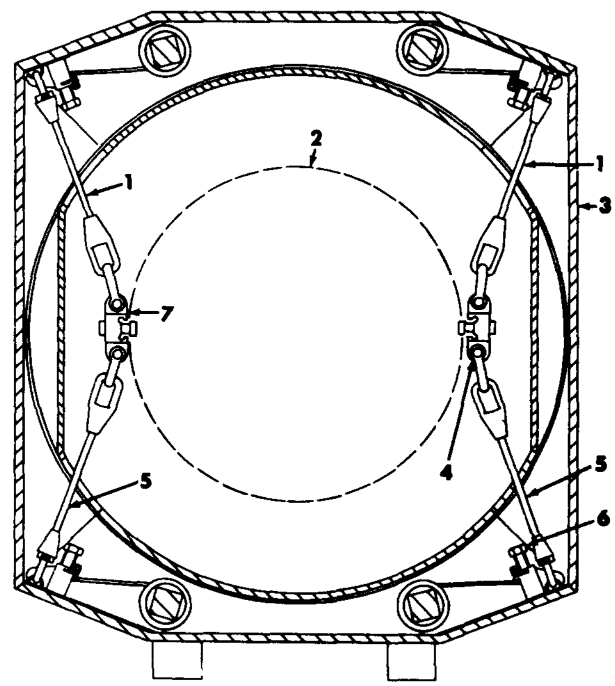
### 5-4.3 "S"-TYPE JARRET MOUNTINGS

Jarret-type mountings consist basically of a steel tube in the shape of the letter "S" with locating pads top and bottom. The tube is filled with compressed elastomer. The mounting operates without any solid friction, using the internal flow of the elastomer as a damping medium. These mountings should normally be used only in compression because tensile forces might cause fracture of the metallic envelope containing the elastomer. Because of its design, the Jarret "S"-type spring is essentially a unidirectional mounting. They are generally used as antivibration mountings. Fig. 5-23 illustrates Jarret "S"-type springs.




1-Adjusting Screw
2-Torsion Bar Lever
3-Wire Rope
4-Shackles
5-Container (stiffener)
6-Torsion Bar Bearing
7-Missile
8-Torsion Bar
9-Wire Rope
10-Carriage Assembly
11-Rails

Figure 5-18. Forward Suspension System and Carriage Assembly




1-Wire Rope
2-Missile
3-Container
4-Shackle
5-Wire Rope
6-Adjusting Bolt
7-Adapter

Figure 5-19. Aft Suspension System

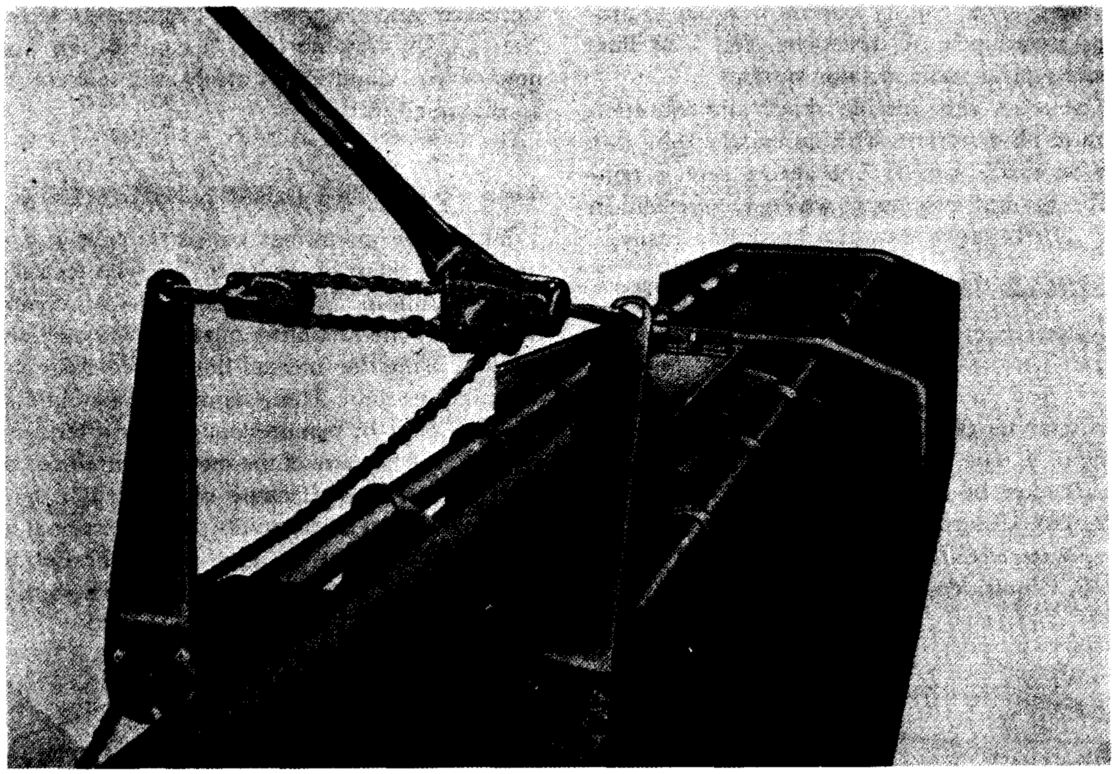


Figure 5-20. Applying Preload Tension to Torsion Bars

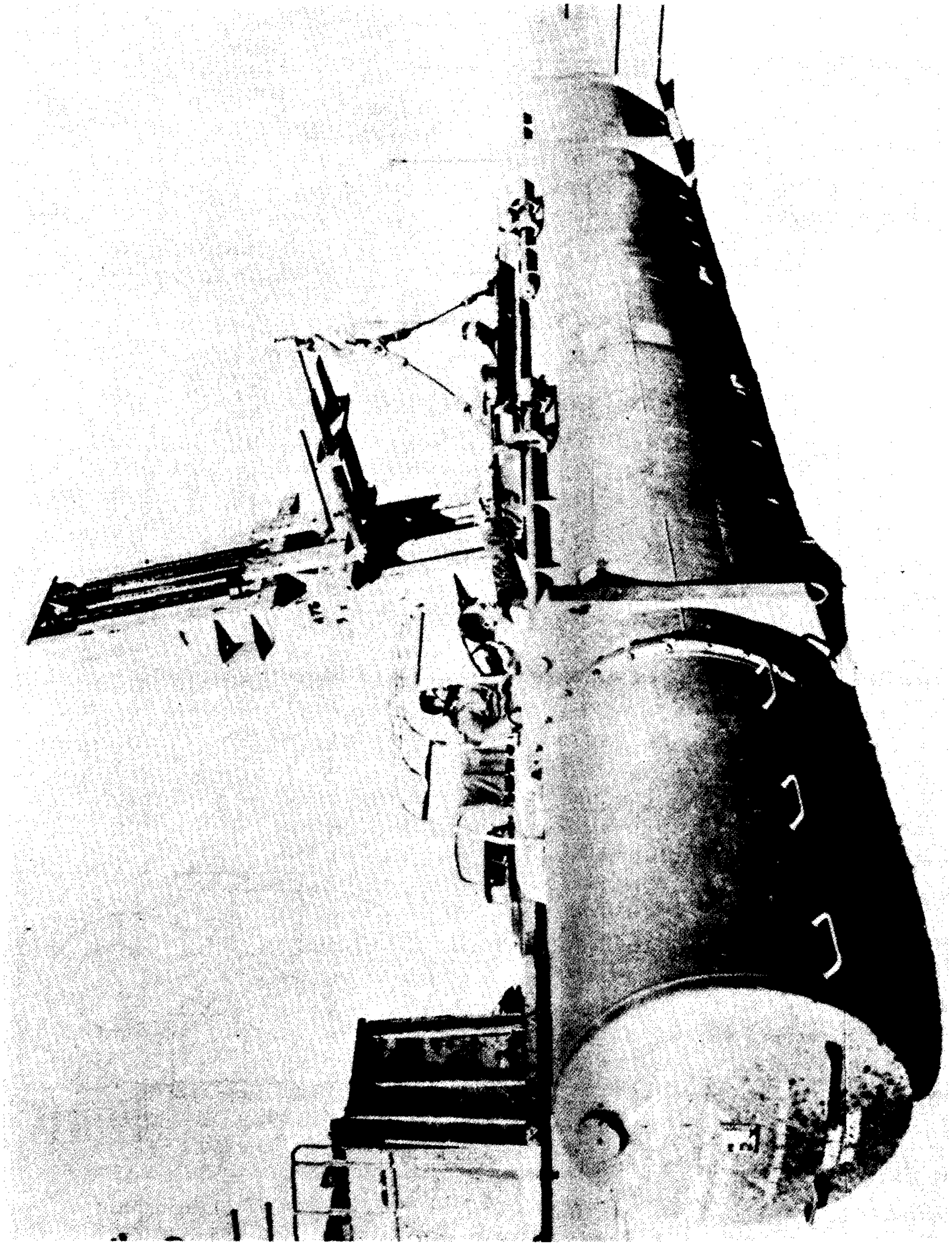


Figure 5-21. CORPORAL M351 Missile Body Container

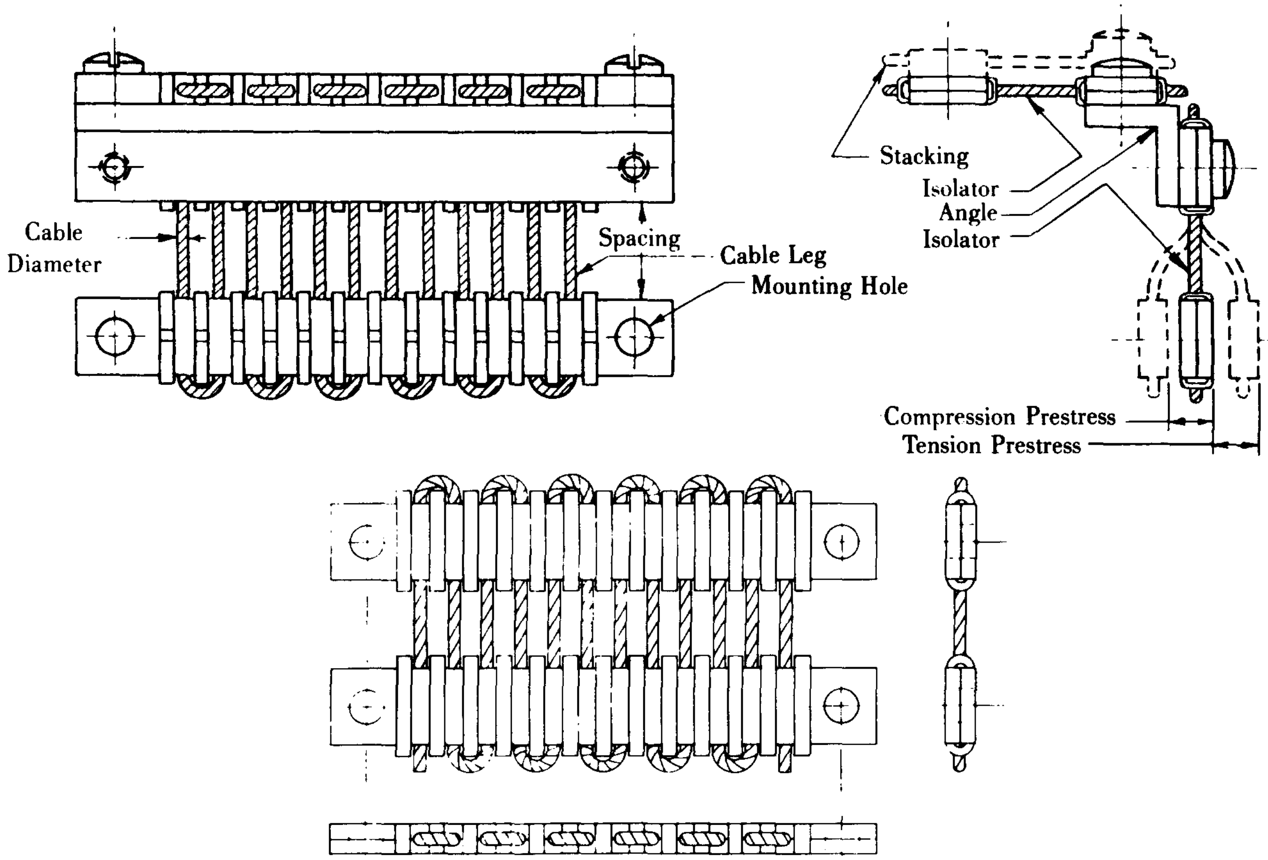
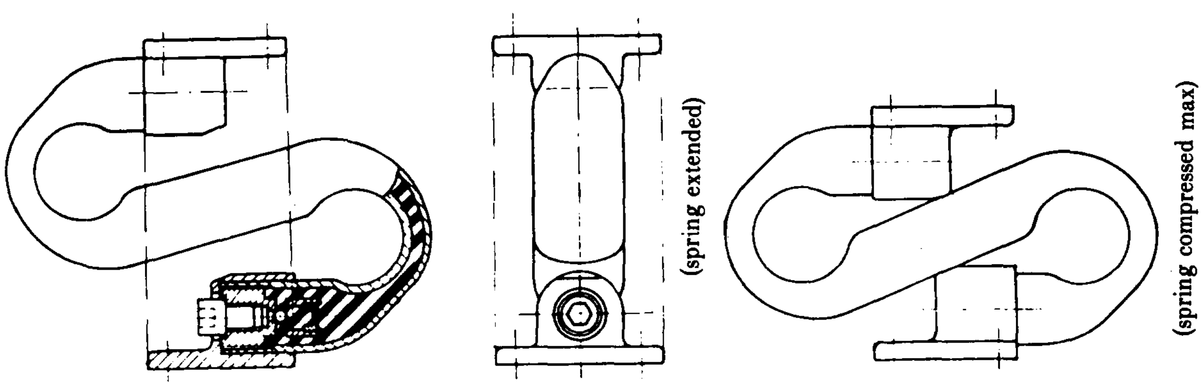



**Figure 5-22. Cable Isolator Assemblies in Two Typical Mounting Attitudes**




This type of mounting is available commercially in the following load ranges:

| Vertical | Transverse | Longitudinal |
|---|---|---|
| 20 to 18,000 lb | 15 to 14,000 lb | 15 to 10,000 lb |

Deflections are 1 to 2 in.

**Figure 5-23. Jarret "S"-Type Mounting**

# CHAPTER 6
# ELASTOMERIC SUSPENSIONS*

*Elastomeric suspension systems—together with their advantages and disadvantages—for rocket and missile containers are discussed. Guidance for preliminary design is presented since final design appears to be an art rather than an engineering science. The importance of mount locations and suspension schemes is emphasized.*

## 6-1 INTRODUCTION

Elastomeric, shear-type sandwich mounts were first developed during World War II to protect aircraft engines. As more fragile and sophisticated weaponry was introduced, the need for protecting these mechanisms became critical. The favorable performance of elastomeric mounts led to their wide acceptance and use in the field of protective packaging and container suspension engineering.

The elastomeric mount offered several advantages. The shear configuration provided sufficient travel to mitigate high shock inputs; it provided equal protection in two planes; its configuration was simple and compact; and the cost of installation was low. Shear mounts have a proven record of reliability; they resist handling abuse and adapt to equipment complexity.

During the past three decades, the impetus in container development has made available a wide assortment of shear mounts, each of which has been specifically tailored to the peculiar requirements of its application (see Fig. 6-1).

Unfortunately, the design technique applied in the development of shear mounts has not been documented nor have the data generated by this effort been consolidated. Consequently, the state of the art is such that each and every application must be analyzed and a mount tailored to satisfy its particular demands. It is probable that an existing design may be identified as capable of satisfying the requirements of a proposed application; however, the performance and physical characteristics of these existing mounts have never been consolidated and the data are not available to provide the container designer with these basic tools to permit general application.

Existing designs encompass a spring rate range of from 10 to 5000 lb/in., and dynamic shear deflection capabilities up to 22 in. Fig. 6-2 illustrates the deflection capability of elastomeric sandwich mounts.

The characteristic of sandwich shear mounts to provide linear displacement and the ability to provide large deflections permit wide design latitude. Shear mounts function to minimize the acceleration of the mounted mass while absorbing and dissipating large amounts of energy introduced by the operating environment. The favorable characteristic of the elastomeric shear mount is depicted graphically in the load deflection curve of Fig. 6-3. This curve is typical of elastomeric mounts in general; however, for a specific mount, the particular performance curve must be developed by test or provided by the manufacturer.

The area below the load deflection curve (Fig. 6-3) is representative of the capacity for energy absorption. The area $E_1$ under the compression curve is equal to the area $E_2$ under the shear curve. It can be seen that the load, and therefore the force needed to develop equal energy absorption, is much higher for the compression mounting than for the shear mounting. For this reason the shear mount with a nearly linear load deflection curve is more efficient than the compression mount whose performance follows a more exponential path.

In addition to the favorable performance cited, many elastomeric mounts usually provide inherent vibration damping characteristics and may, under certain conditions, obviate the need for additional auxiliary damping devices. There are also an assortment of elastomers available which will satisfy the temperature range requirements of the worldwide distribution environment.

A review of military containers demonstrates the technical feasibility of shear mount suspension systems. Economic feasibility generally is limited to reusable containers or those subject to selective salvage (see Chapter 8).

*The information used in this chapter is based on data furnished by Lord Manufacturing Co., Erie, PA.

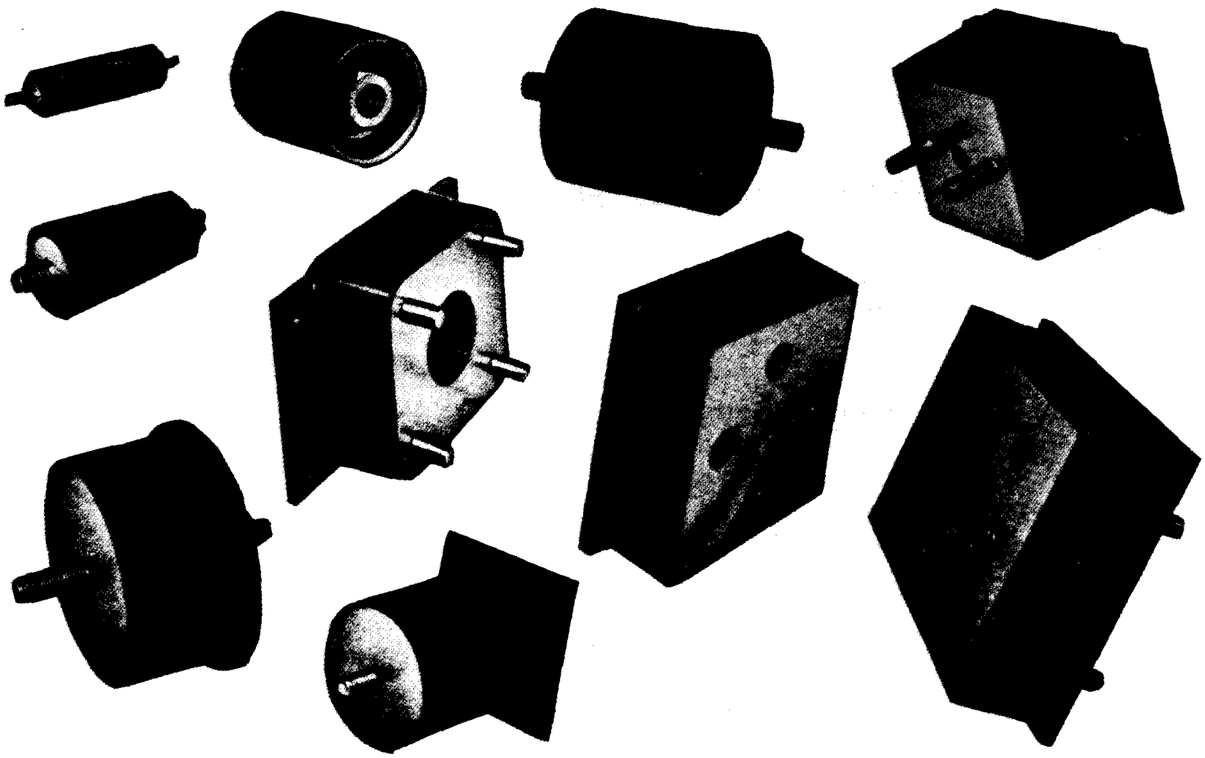
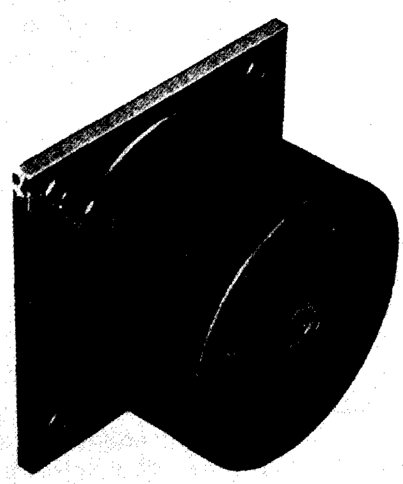


Figure 6-1. Shear Mountings—Sandwich Construction



(A) Mount

(B) Test Demonstrating Large Deflection Capability and High Strength Bond

Figure 6-2. Deflection Capability of Elastomeric Sandwich Mount

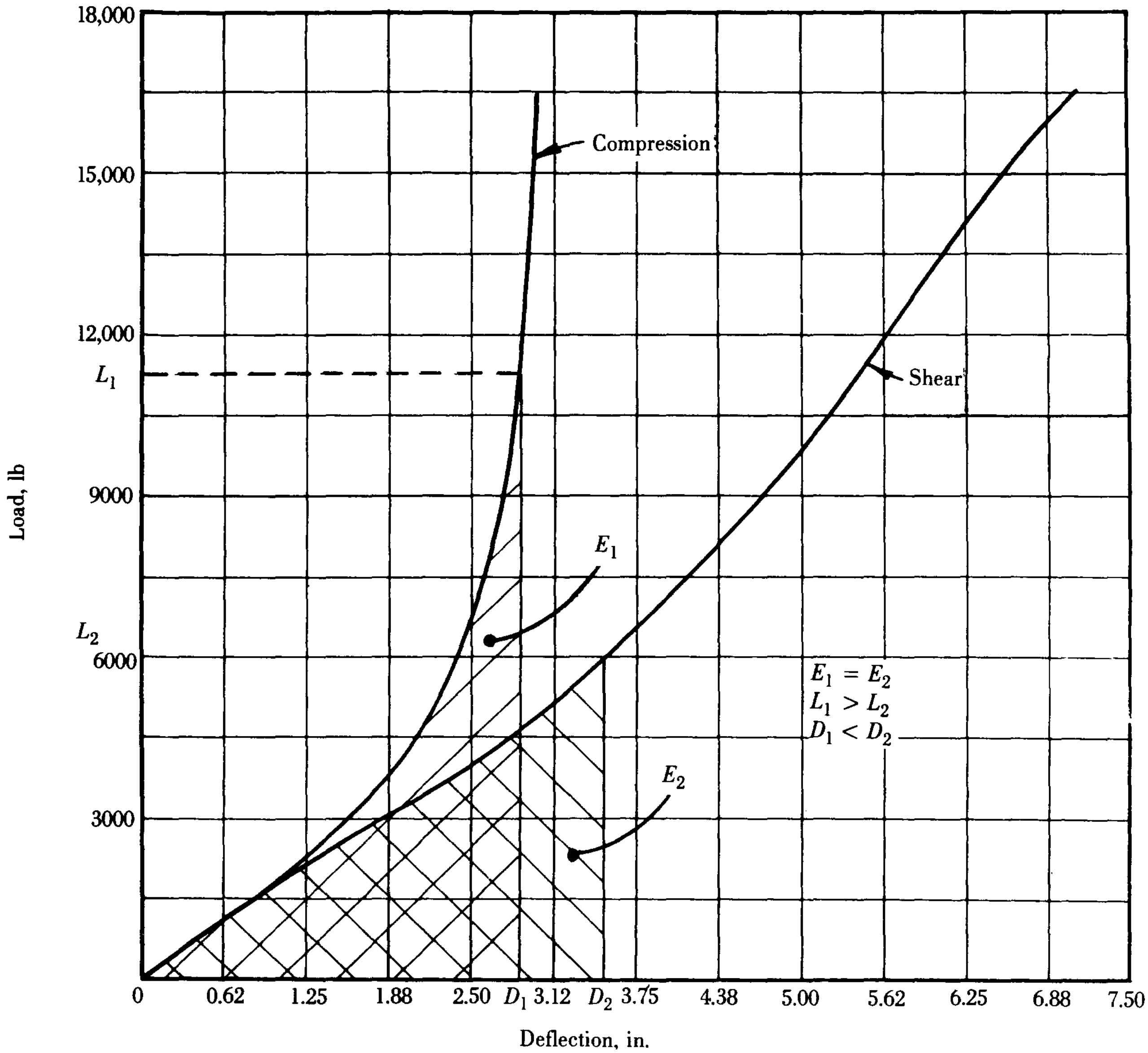



**Figure 6-3. Typical Load Deflection Curve for Elastomeric Mounts**

# 6-2 DESIGN

## 6-2.1 GENERAL

The preferred approach in the process of container design is to develop the suspension system first. When the sway space—as determined by the required spatial displacement—has been calculated and the proper mounts have been selected and their location established, then, the container can be designed.

Unfortunately, the present state of the art does not provide sufficient data to permit the designer to make a mount selection. Consequently, elastomeric shear mounts cannot be considered as standard off-the-shelf hardware; they must be tailored to the application by the mount supplier. As inconvenient as this may be, the designer must resort to this procedure; he must consult and collaborate with the mount supplier in the selection of a suitable shear mount suspension. Since application data are not available, this design handbook can only provide a suggested approach to the problem; one which will result in expeditious resolution of the mount selection. The designer must, however, retain control of all aspects of design and/or application and not permit the supplier to introduce characteristics or restrictions favoring one product or source of supply. Because of this necessary marriage of convenience between the container designer and the mount supplier, the initiating agency should request and expect from the mount supplier assurance and certification of performance.

As just mentioned, the design and/or selection of a particular shear mount must be the result of collaboration with the mount supplier. The container designer must provide the mount supplier with the details of the proposed application and provide sufficient data to permit a comprehensive analysis and subsequent mount recommendation.

The many factors affecting mount performance cannot be mathematically expressed in any simple or series of simple equations. The design and application of elastomeric shear mounts have yet to attain the status of a pure technology, and the technique involved cannot be conveniently conveyed. Until this deficiency has been satisfied by the development of a practical analytical design procedure, the selection and/or design of a specific shear mount must remain within the domain of specialists—usually found in the employ of mount suppliers.

## 6-2.2 PROBLEM DEFINITION

Consequently, the container designer must establish the performance criteria and convey these data to the mount supplier early in the program to expedite the container development. The information required by the mount supplier is tabulated and should be as complete and accurate as possible, namely:

a. Identification and description of the item to be protected. (The name and description of the item are important since they provide a reference designation for the particular application and give the suspension system designer an idea of what he is working on.)

b. Weight of the item

c. Weight of the cradle or fixture used to support the item

d. A sketch of the item showing overall envelope dimensions, permissible points of attachment or support, and the center of gravity. (The purpose of subparagraphs b, c, and d is to establish the total suspended weight or the weight the mountings will support. It has been found desirable to list the weight of the cradle separately in order to call attention to it since cradle weight frequently is ignored. A sketch of the unit, the attachment points, and the location of the center of gravity are all necessary to establish the reaction load on each of the mountings; however, when cradles are used, it is not necessary to restrict the location of the mountings to the attachment points. Also, if there is a reason why the mountings should be located in one particular place, this should be noted since it will influence the selection of the mountings.)

e. The fragility factor of the item and the temperature, direction, and location at which it shall be measured and/or tested. (Fragility factor information is frequently passed over without enough consideration. Since some of the container applications require protection down to $-65°F$ and others require protection to room temperature conditions only, it is important to know the temperature at which the $G$-load will be measured. Some units also have different fragility levels or different axes for directions of impact. When subjecting the unit to an edgewise rotational drop test, it is important to know where on the unit the $G$ forces will be measured.)

f. The shock imposed upon the item, the type of drop and drop height or the magnitude of $G$ input, and the pulse time and its shape. (If the shock input is expressed in terms of $G$'s, it is essential that the time duration of the pulse and the pulse shape be included since $G$ input by itself does not define the amount of energy going into the container.)

g. The testing procedure, the number of drops, and the temperature at which testing will be conducted. (This requires details of the testing procedure since on occasion the number of drops and the

temperatures at which the drops are conducted will actually represent a fatigue test that will control the selection of the mountings.)

h. The vibration inputs imposed upon the test item. (Some military specifications include vibration test and resonant dwell requirements that exceed the normal mounting requirements of the shock protection—in other words, the mountings are selected primarily to meet the vibration test requirements since the vibration tests are more severe than the shock protection requirements. The allowable vibration output or the vibration tolerance of the unit is frequently different than the fragility factor since the fragility factor applies to a shock input, whereas the vibration tolerance will refer to the ability of the unit to withstand a steady state vibration. This information is not generally available and can be quite complicated since the vibration tolerance would have to be defined in $G$'s as well as frequency in most instances.)

i. The allowable vibration limits to be experienced by the suspended item

j. The normal shipping attitude of the item

k. The moment of inertia of the protected item. (Moment-of-inertia data are important if the shock requirements include an edgewise rotational drop or end impact testing. If this form of testing is included, moment-of-inertia data are essential and must be approximated before an analysis can be made.)

l. The moment of inertia of the cradle support. (This can have the same effect as the weight of the cradle as far as distorting the actual suspended weight. Mounting space limitations are important if the designer wishes to limit the thickness or width into which the mounting must be installed. This applies especially in cases where an existing container is being used for new applications. The container dimensions, as requested in subparagraph p, would apply in those instances where an existing container is being used.)

m. Applicable restrictions peculiar to the item or the application

n. A description of the transit environment

o. A description of the climatic environment affecting mount performance

p. Description of the container and its dimensions

q. Special testing requirements

r. Other pertinent data.

### 6-2.3 PRELIMINARY DESIGN

Having defined the problem and submitted the required data to the mount supplier, the container designer may proceed to apply several rules of thumb to provide an indication as to the size of the container and the effect the suspension system will have on the container design. All "ball park" figures generated by these rules of thumb must be modified upon receipt of specific data and recommendations from the mount supplier.

The data given in Fig. 6-4 set forth very useful information concerning the relationship among drop height, natural frequency, acceleration, and deflection. The designer can determine, simply on the basis of drop height and fragility factor, what natural frequency the system will have and approximately how much deflection will result from the drop tests. By adding an inch or two to the deflection figure, the designer can approximate the sway space between the unit and the inside of the container and, thus, the size of the container.

Various factors affect the design of a shipping container mounting system—shock requirements, natural frequency, size, stability, and others. To arrive at a practical system, these must be balanced. If shock requirements will permit, the natural frequency should be higher than 7 Hz. An example problem follows.

*Given:* Item Size = 36 in. long × 24 in. wide × 15 in. high
Flat drop height $h$ = 30 in.
Item weight = 125 lb
Center of gravity located at geometric center
Fragility factor $G_m$ = 25
Number of convenient attaching points exist along lower sides on the long axis.

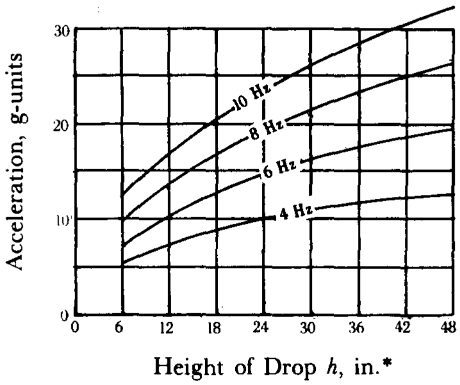
*Object:* Selection of mountings.

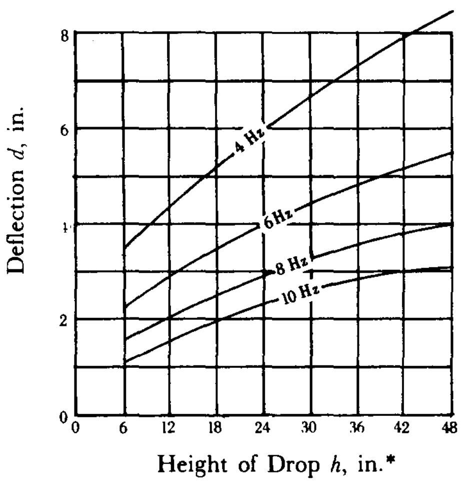
With this information, the first step is to determine the spring rate $k$ and deflection $d$ of a suitable mounting system.

To determine the deflection of the mounting system, use Eq. 1-5.

$$d = 2h/(G_m - 2)$$
$$d = 2(30)/(25 - 2) = 2.6 \text{ in.}$$

(For "ball park" figure of sway space required, add 2 in.)




*Adjusted to include deflection across mountings

### DESIGN GUIDE

This useful guide has been developed by Lord** to show the relationship of drop height $h$, deflection $d$, fragility factor $G_m$, and natural frequency of a suspension system $f_n$.

Designers and packaging engineers will find this guide valuable in two ways:

1. *Gain a rapid understanding of the factors involved in a suspension system:*

For example, note that $G$ and $d$ are inversely proportional; as the fragility factor is lowered, larger deflections must be provided. And $d$ determines the sway space that must be provided within the container.

The guide also shows whether the proposed system has compatible shock and vibration requirements. Certain $G_m$ limits will place the $f_n$ in the critical 2- to 7-Hz range. In this instance, either a stiffer suspension must be adopted (which raises the $G_m$ limits), a lower drop height must be accepted, or damping must be introduced to control motion under the resonant conditions.

2. *Get a quick approximation of $h$, $d$, $G_m$, and $f_n$:*

The guide permits you to:

a. Find $f_n$ and $d$ when $h$ and $G_m$ are known. This is the usual case since most specifications call out the drop height and $G_m$ limits.

b. Find $G_m$ for various suspension stiffnesses (expressed as $f_n$) after assuming $h$. Stiffness affects $d$ and ultimate choice of mounting.

c. Find $h$ when you know $G_m$ by assuming $f_n$.

d. Find $h$ for various $f_n$ when you know $d$. This is the case when it is necessary to use an existing container. The available sway space determines the maximum permissible $d$. Note that $h$ will be limited by the $G_m$ that the equipment can withstand.

** Lord Mfg. Co., Erie, PA

**Figure 6-4. Relationship of Drop Height, Deflection, Fragility Factor, and Natural Frequency of a Suspension System**

The value of $L$ can now be determined by using the procedure outlined in par. 5-2.1.3.

*Note:* The calculations shown here are simplified for purposes of clarity. In order to design and select a mounting system that is satisfactory for all conditions, end impacts, side drops, end drops, rollover tests, and natural frequencies in all modes must also be considered (see Chapter 1).

## 6-2.4 MOUNT LOCATION

Having established an approximate value for the required sway space, the designer may then approximate the dimensions of the container. The internal dimensions of the container must provide for the unrestricted movement of the suspended item. The sway space or amount of clearance must be provided both below and above the suspended mass and at both ends to provide for both deflection and rebound experienced when subjected to shock loading. The rules that follow are applicable and are provided as guidance in the development of the concept and subsequent design of the container.

The mounts should be placed as far apart as practical for stability. The center-to-center spacing of the mountings in the lateral direction should be about three times or more the distance the center of gravity is above the mounting plane. This dimensional relationship generally will avoid serious coupling problems that result in instability. In the longitudinal direction, the spacing of the mounting should be about five times or greater than the distance of the center of gravity above the mounting plane. In all cases, the mountings should be spread as far apart as possible, as mentioned previously. There are installations in which these rules cannot be applied; however, special attention must be given to the application to be sure the coupled natural frequencies will not cause a vibration problem. Fig. 6-5 is a lateral view of a typical suspension system.

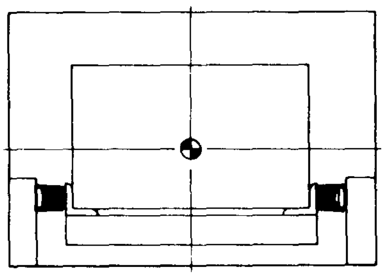


Figure 6-5. Lateral View of Typical Suspension System

In the plan view, the mounts should be symmetrical with respect to the center of gravity, or, if this is not possible, the mountings should be selected and located so they will have the same static deflection. It is conceivable that the mountings would also have to be selected in different sizes to produce the same stress on each mounting. Generally speaking, however, it is possible to locate the mountings symmetrically about the center of gravity to avoid using two different types of mountings in the same container. Fig. 6-6 is a plan view of a typical suspension system.

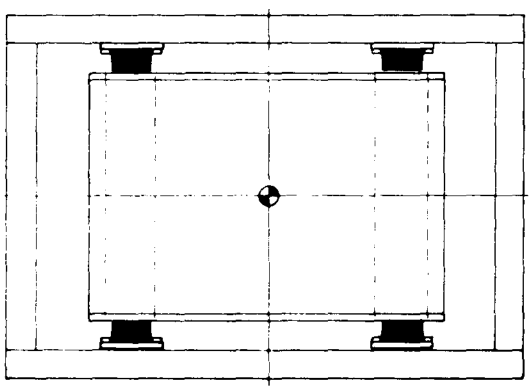


Figure 6-6. Plan View of Typical Suspension System

When multiples of mountings are used, they should be clustered at the extremities of the unit in preference to spacing them along the structure. This technique will avoid an excessively low natural frequency in the pitch mode.

Be sure to avoid interferences that will contact the mountings when they deflect, and either abrade them or possibly tear them.

Allow several inches of sway space on all sides as well as the top and bottom of the mounted unit. The amount of such space depends on the size and shape of the equipment, and on the rough handling anticipated.

### 6-2.5 MOUNT ORIENTATION

Conventional shear mount applications position the assembly with its shear plane vertical, at right angles to and parallel with the longitudinal axis of the suspended item to be protected (see Fig. 6-7). In this position, shear mounts provide excellent protection in both the vertical and longitudinal directions.

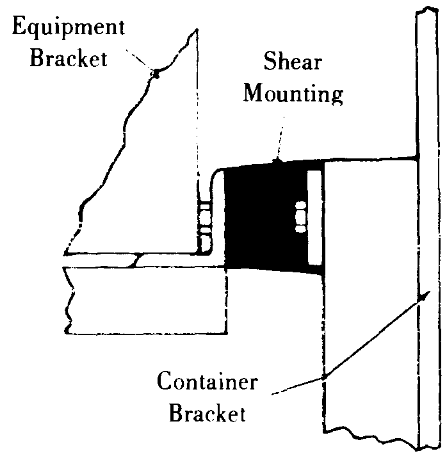



Figure 6-7. Conventional Shear Mount Orientation

Side drops subject the conventional suspension scheme to compressive forces negating the excellent shear performance of sandwich mounts. Due to their physical configuration and inability to provide any appreciable compressive deflection, the shear mount can be considered to provide little or no shock mitigation when subjected to compressive loading. However, the logistic environment normally subjects the container to vertical and longitudinal impacts; lateral impact loading is most infrequent. The usual configuration of the container and its normal shipping attitude preclude the necessity for maximum lateral protection since the container will either roll or tip over, thus transmitting to the suspended mass only a fraction of the imposed shock of impact. Suspension system design technique usually positions the shear mounts below the center of gravity of the suspended load, thus introducing a couple which functions to further mitigate the effects of the imposed shock.

In considering the location of the elastomeric mountings, it should be noted that a typical missile container system may have two pairs of shock and vibration isolators spaced symmetrically about the

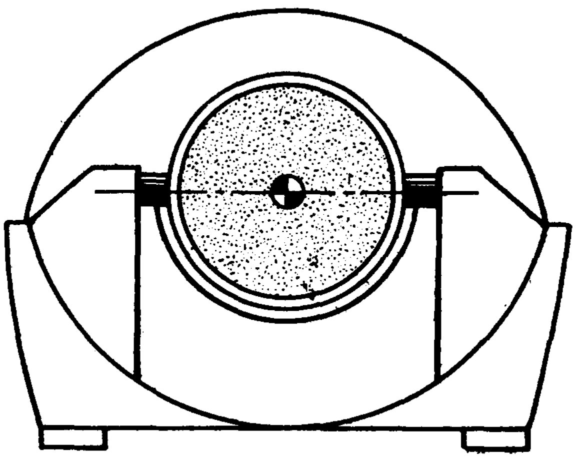
spring mass center of gravity in side elevation. With a symmetrical spacing of isolators, the spring rate for each can be the same. The longitudinal spacing of isolators is based on pitching frequencies and on deflection of the isolators. The farther apart the isolators are longitudinally, the greater the pitching frequencies and the larger the deflection of the isolators for a given acceleration. Since isolators have a definite deflection range, such range often dictates the longitudinal spacing of the isolators.

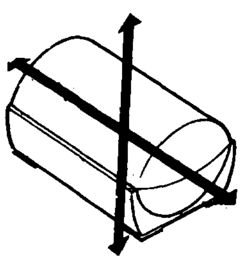
The spring rate for each pair of isolators in a system need not be the same, provided their static deflections are the same. In a system where the missile attachment points are such that the missile can be made to work structurally as a link in the suspension system, a simpler system results with the elimination of longitudinal rails and the use of two pairs of isolators which have different spring rates.

### 6-2.6 SUSPENSION SCHEMES

The position of sandwich mounts and their location with respect to the center of gravity of the suspended mass can either enhance or degrade the performance of the suspension system. Common suspension schemes are depicted in Figs. 6-8 through 6-11; the advantages of each arrangement are described in the pertinent caption.

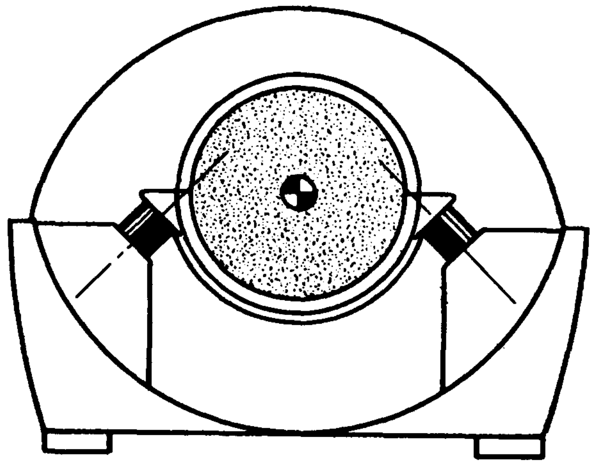
Figs. 6-12, 6-13, and 6-14 show typical design alternatives for situations where severe space limitations exist or the item has an unusually low fragility factor.

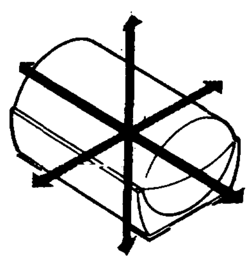




This system provides maximum shock protection in the vertical and fore-and-aft directions, where maximum shock is expected, and a lesser amount in the third (lateral) direction, where little shock is expected. Shear sandwich mountings are located in same plane as equipment center of gravity.

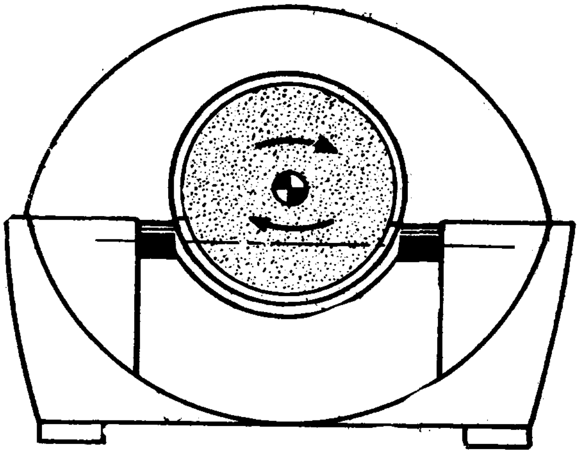
Figure 6-8. Vertical System

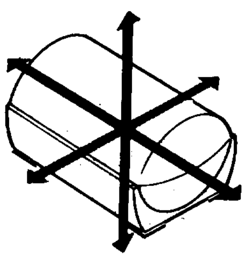




Where mountings cannot be located at the plane of the center of gravity, they can be arranged to project the system elastic center to coincide with the center of gravity. This provides good vertical and lateral protection, plus maximum fore-and-aft protection.

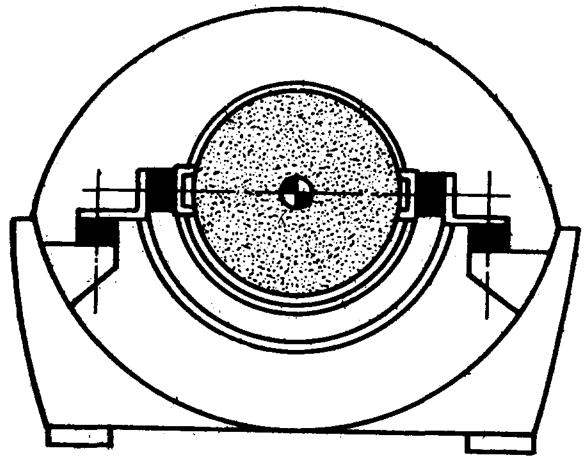
Figure 6-9. Focalized System

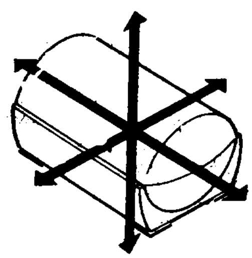




Protection in 3 directions can also be achieved by locating the mountings in a plane below the center of gravity so that lateral inputs will result in controlled rotation of the unit about its elastic center. This provides good lateral protection plus maximum vertical and fore-and-aft protection.

Figure 6-10. 3-Direction System





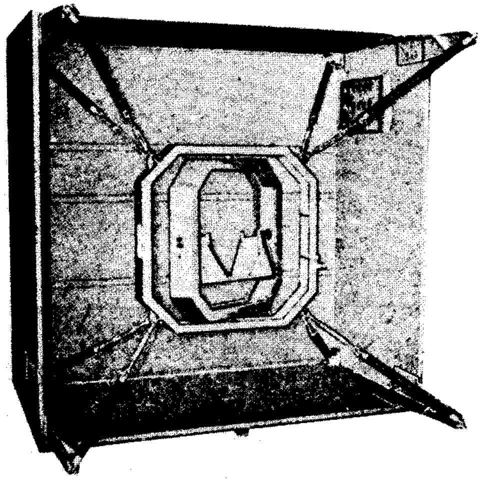
(RARELY USED)

This type of system provides the needed protection in all directions for equipment that has low fragility factors along the 3 principal axes and is susceptible to maximum shock along these same axes. The arrangement uses 2 shear sandwich mountings at each attachment point at right angles to provide large deflection capabilities vertically, fore-and-aft, and laterally. This assures maximum all-attitude protection.

Figure 6-11. Gimbal System

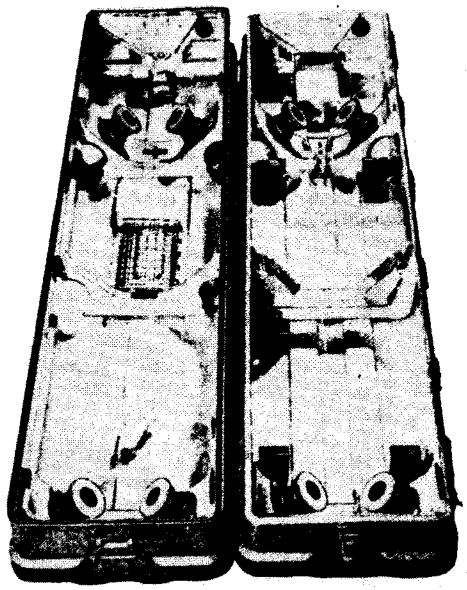
## Typical System Design Alternatives

Where extremely unusual requirements exist, such as severe space limitations or exceptionally low fragility factors, other elastomeric mounting designs may be employed:



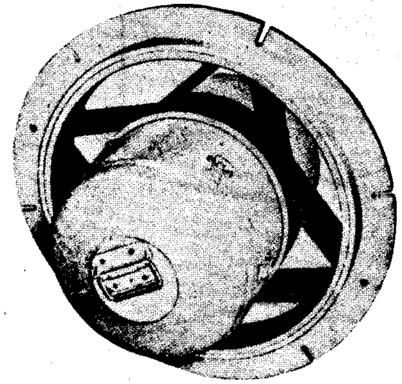
This 8-corner mounting arrangement combines the principle of rubber-in-shear with tension and compression. It is especially effective for ultrasensitive equipment, provides low fragility protection, withstands severe abuse, and insures all-attitude protection.

**Figure 6-12. Special All-Attitude System**



Systems incorporating the buckling column principle of shock control may be used for maximum protection with minimum deflection and sway space inside the container. Under shock, the elastomeric section buckles and provides high energy absorption for a given deflection.

**Figure 6-13. Buckling Column System**



This unit is a special adaptation of the buckling column principle. The design is suitable for cylindrical objects of any diameter and provides approximately equal protection in all directions.

**Figure 6-14. Elastomeric Ring Mounting**

# CHAPTER 7
# BULK CUSHIONING

*A background on cushioning systems is presented to assist the designer in the solution of cushioning problems. Characteristics of the more commonly used cushioning materials—polyurethane, polyethylene, and rubberized hair—are given. To facilitate cushioning design, available analytical data and models—together with examples of the methodology—are discussed in order that the designer may find an economical, satisfactory solution to his cushioning problems.*

## 7-0 LIST OF SYMBOLS

$A$ = cross-sectional thickness of pad
$A_T$ = effective bearing area for completely encapsulated item in cornerwise-drop
$A'_T$ = effective bearing area for item protected by corner pads in cornerwise-drop
$c$ = coefficient for each variable combination
$c_0$ = constant term in regression model
$d$ = depth of item to be protected
$G$ = imposed shock, g-units
$(GL)_{max}$ = maximum fragility level of protected item, g-units
$h$ = height of protected item
$i$ = index for transformation exponent
$j$ = index for temperature exponent
$k$ = index for thickness exponent
$\ell$ = index for drop-height exponent numerator
$L$ = length of item to be protected
$S$ = length of one side of corner pad
$SS$ = static stress
$SSL$ = static stress lower
$SSU$ = static stress upper
$T$ = thickness of cushioning material required without regard for creep
$T_c$ = thickness of cushioning material required to compensate for creep
$T_x$ = minimum thickness of cushioning material to protect all sides of item
$W$ = weight of item
$w$ = width of item to be protected
$\theta$ = temperature, °F

## 7-1 INTRODUCTION

The objective of this chapter is to provide a cushioning-oriented background for the container cushioning system designer to assist him in the solution of bulk cushioning problems. The material contained in this chapter reflects the efforts of the Air Force Packaging Evaluation Agency through MIL-HDBK-304A, the US Army Missile Command (MICOM) through the MICOM cushioning research reports, and Picatinny Arsenal through the Plastics Technical Evaluation Center (PLASTEC). The results of these efforts have been adapted and expanded, where necessary, to meet the needs of Army rocket and missile containers.

Discussed are the more commonly used cushioning materials in Army container programs, namely, foamed polyurethane (ester and ether types), foamed polyethylene, and rubberized hair.

Recent research efforts have produced mathematical models for selected cushioning materials, which permit the packaging designer to determine cushioning requirements with considerable confidence. However, sound judgment in conjunction with the developed models is still required to achieve efficient cushion design.

To facilitate cushioning design, this chapter presents a discussion of the available analytical data and models together with the practical considerations that must be understood and used by the package designer to achieve satisfactory and economical cushioning problem designs.

## 7-2 GENERAL

The cushioning state of the art has progressed rapidly during the past several years. Recent materials research has provided several "plastics"-based materials for use as strong, yet lightweight, cushioning systems. These new materials have virtually replaced the less exotic materials—such as shredded paper, popcorn, or sawdust—as the basic cushioning material.

Due to the nature of these new materials, together with the many factors affecting their performance, it has been considered impossible to develop one mathematical expression capable of describing the behavior of the entire class of "plastics" materials. However, if each material is considered individually, it is possible to acquire satisfactory mathematical expressions for a range of parameters for a single density of that material. Then the analytical design may be subjected to laboratory test to verify the calculated performance.

Bulk cushioning systems allow the item being protected to continue its motion after the container has impacted upon some surface. The cushion pad thickness, the compressive characteristics of the cushioning material, and the drop height determine the amount of shock to which the item will be subjected. The resistance of the material to compression determines the rate of deceleration of the item within the container. The thickness of the cushion pad is determined by the distance through which the item must decelerate before coming to rest. The selection of the cushioning material will be influenced by the weight, weight distribution, and fragility of the item to be protected, together with the expected temperature range which the protected item will encounter. Frequently, there will be several cushioning materials possessing the desired physical characteristics. The choice will then be influenced by cost factors, availability of material, and the physical limitations imposed upon the container.

Compressibility is an important characteristic in bulk cushion selection since it represents a measure of cushion deflection under load. However, this characteristic is a function of material type, density, thickness, and temperature. It is necessary to test each material under the same conditions if equitable comparisons are to be made. Frequently, the cushion manufacturer will provide stress-strain (load-deflection) curves for his material at 70°F to promote application of his product. Unfortunately, real world applications are *not* exclusively at 70°F which leaves considerable doubt concerning the cushion performance at temperature extremes. In addition, there is considerable difference between static loading and in-service shock loading. Since shock loading is of a dynamic nature, the use of only stress-strain curves in missile container design is *not* recommended.

The general classification of bulk cushion is based on the manner in which it performs and responds under loading as reflected by the shape of its force-displacement curve. The manner in which cushion materials respond to loading is depicted in Fig. 7-1 and categorizes these materials into types (Ref. 1).

A review of the plotted data indicates that:

1. As the displacement increases, the force necessary to produce each additional increment of displacement also increases. Of significance is the rate and manner in which this force increases.

2. As the material compresses, it becomes more dense and its resistance to compression increases; consequently, the force necessary to result in further compression (deflection) must necessarily increase. This characteristic is peculiar to all conventional cushioning materials, and their performances vary only in the manner and rate in which they respond.

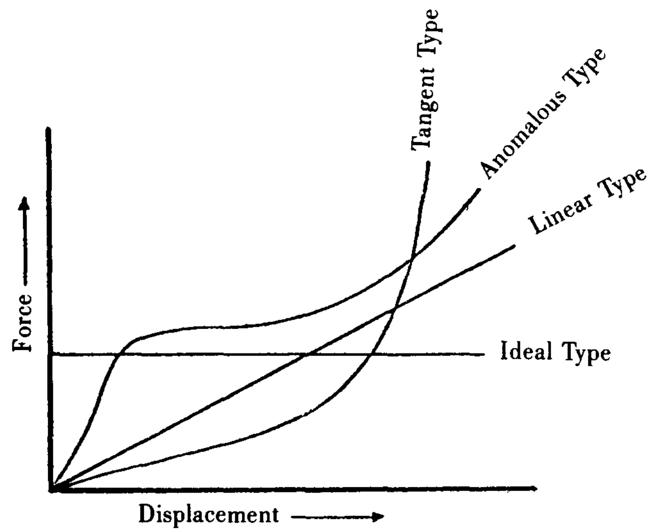



**Figure 7-1. Force-Displacement Curves for Various Types of Cushions**

3. The type performing most favorably is that designated as "anomalous" which provides a range of cushion performance comparable to that of the ideal.

4. The tangential type is applicable only within a certain range beyond which the cushion attains a density approaching that of nonresiliency and its cushioning effects become nil. This condition is referred to as "bottoming", and the full force of impact is transmitted to the displacement contents.

5. The linear type is limited in application by the displacement required to attenuate shock and the spatial limitations placed upon the container.

The more commonly used anomalous type cushioning materials include urethane foam (both ether and ester types), foamed polyethylene (including chemically cross-linked), and rubberized hair (edge loading). Rubberized hair, when loaded flatwise, would be considered a tangential type cushioning material.

Since stress-strain curves do not describe the dynamic behavior of a cushioning material, the usual approach is to employ the relationship between peak acceleration *G*'s and the corresponding static stress. This approach results in a family of curves for each material thickness at each drop height. The resulting curves are referred to as dynamic cushioning curves which have been generated for a particular cushion material thickness by performing drop tests using standard weight specimens which are dropped onto the cushion. A different curve is required for each

drop height, thickness, density, and material type. Until recently, available dynamic cushioning curves were confined to 70°F. Incorporation of a worldwide distribution environment further compounds any cushioning data problem. Since US rockets, missiles, and military weapons are in constant readiness for transport to all parts of the world, temperature extremes extend from -65°F to +160°F (Army Regulation 70-38, Climatic categories 1 through 8). Consequently, cushioning systems must be capable of functioning over this temperature range if adequate protection is to be provided.

Effort has been expended to determine the effect of temperature extremes on the properties of container cushioning systems. Fig. 7-2 illustrates that the accelerations will generally be higher for a drop test at -65°F than for one at +70°F (Ref. 2). This is to be expected since the cushion material increases in stiffness as the temperature is reduced (Ref. 3). Another effect of temperature is seen in Fig. 7-3 where cushion material strength increases with decreasing temperatures for this particular polyethylene foam (Ref. 2).

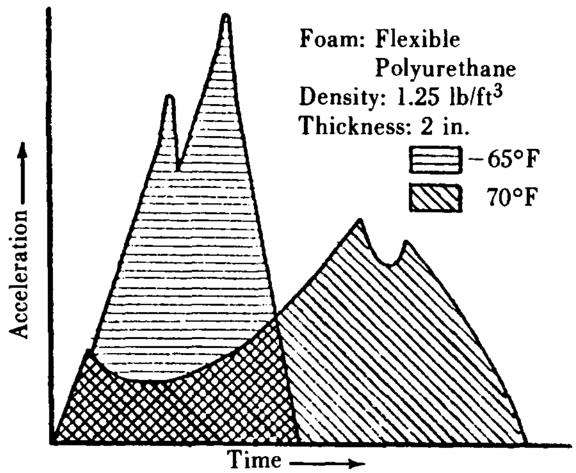



**Figure 7-2. Acceleration vs Time Traces for a Typical Polyurethane Cushioning Material Dynamically Loaded at 70°F and -65°F (Ref. 2)**

Rather than incorporate additional protection into the equipment to compensate for the worldwide distribution environment, it is much more cost-effective to improve the reliability of the cushioning system. This may be accomplished through the use of the superimposed dynamic cushioning curve approach. This approach superposes the dynamic cushioning curves, developed at the temperature extremes, upon the 70°F curve. This handbook advocates this approach and will present design procedures based upon the superimposed dynamic cushioning curve technique.

In many instances, a military container will be subjected to repetitive abuse; therefore, the ability of the cushion to recover is of prime importance. Many of the common cushioning materials are resilient and will recover upon removal of the applied load. This characteristic must be considered in the material selection process.

Nonresilient cushions, when subjected to a dynamic impact, experience a displacement resulting in permanent set, with no recovery. Unless this set is external, the effect of impact results in loss of restraint and the item to be protected is free to vibrate within the confines of the container. This loss of restraint introduces a condition detrimental to the protective function of the container. When exposed to a vibratory environment, the unrestrained item may not necessarily vibrate in phase with its container and will produce a hammering action tending to pulverize its protective cushion. Unless deflection can be localized and restricted to those surfaces not affecting physical restraint of the protected item, it is recommended that a resilient cushion be used.

The resiliency of the material and its ability to recover result in rebound and introduce harmonic vibrations which, if resonant with the natural frequency of the cushion system, will result in damage to the contents of the container. At present, much additional research is needed to develop quantitative data relating to the vibrational aspects of bulk cushioning. Until this deficiency is satisfied, empirical testing of the developed prototype is necessary.

## 7-3 CUSHIONING MATERIALS

Many cushioning materials are not suited to missile container application and, consequently, will be mentioned only briefly. However, several of the more recently developed cushioning materials are capable of providing the desired protection and will be discussed in depth.

Excelsior, shredded paper, sawdust, and other similar substances are not considered to be suitable for the protection of missiles and rockets due to their high moisture absorption rate, their tendency to disintegrate and decay, and their vulnerability to permanent set. These materials are mentioned only for historical significance since they have been used previously in military packaging applications.

The current materials ordinarily used as military

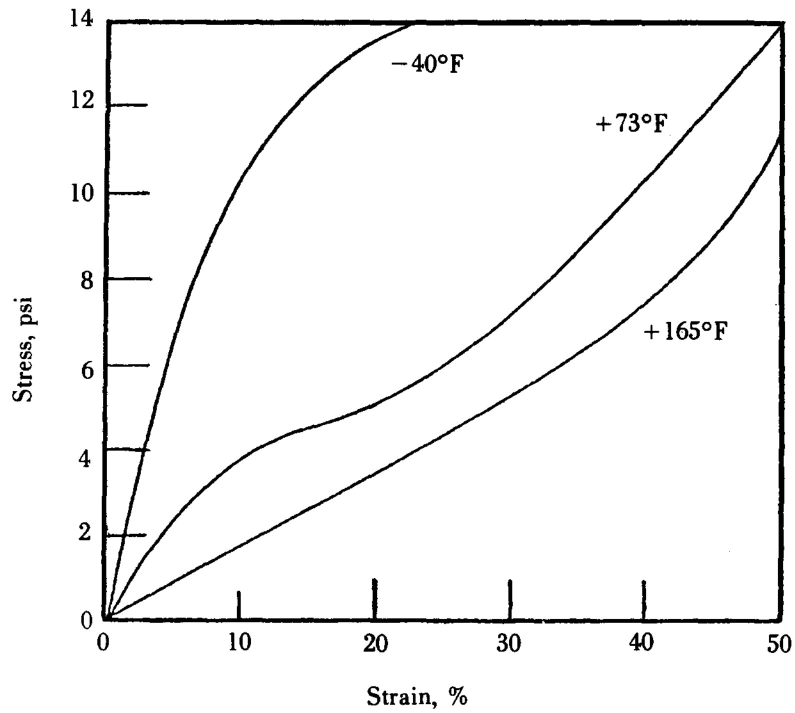



**Figure 7-3. Compressive Stress-Strain of Low Density Polyethylene Foam at Various Temperatures (Ref. 2)**

cushioning systems and considered capable of providing the required protection include:

a. Polyethylene foam per PPP-C-1752, *Cushioning Material, Packaging, Unicellular, Polyethylene Foam, Flexible*

b. Urethane foam per MIL-P-26514, *Polyurethane Foam, Rigid or Flexible for Packaging*

c. Rubberized hair per PPP-C-1120, *Cushioning Material, Uncompressed Bound Fiber for Packaging.*

Extensive drop tests at several temperatures have been performed at MICOM on three polyethylene foams (2.0 lb/ft$^3$ Minicel*, 2.0 and 4.0 lb/ft$^3$ Ethafoam†), two polyurethane foams (3.0 lb/ft$^3$ ether type and 4.0 lb/ft$^3$ ester type), and type IV and type V rubberized hair. The densities specified are nominal values since production tolerances exist.

### 7-3.1 POLYETHYLENE FOAM

Foamed polyethylene is a closed cell, lightweight material with each cell closed off from its adjacent cells. It is a tough, resilient material having good flexibility characteristics. Polyethylene foam can be shaped with conventional hand tools or power tools. However, due to its flexible nature, it is most easily shaped by tools with blades or bits having a slicing type action. Other means of shaping include the use of electrically heated resistance wires or thermal shaping through the use of contoured molds with heating and cooling capacities.

Polyethylene foam displays excellent shock mitigation characteristics for military cushioning applications. Energy absorbed during a sudden shock is not released with equal rapidity, thereby causing a relatively slow rebound rate. Based upon its relatively predictable properties, polyethylene foam is one of the most frequently used cushioning materials.

Polyethylene foam has the ability to withstand temperatures from -65°F to +160°F. However, extreme temperatures cause the foam to function in a different manner than at 70°F. Consequently, the temperature effect is shown for the Minicel cushioning material at -65°F, +70°F, and +160°F; for thicknesses of 1, 2, and 3 in.; and a drop height of 30 in. in Figs. 7-4 through 7-6, respectively (Ref. 4). Similar information is provided for the 2.0 lb/ft$^3$ and 4.0 lb/ft$^3$ Ethafoam material in Figs. 7-7 through 7-12 (Ref. 5). It should be noted that the curves presented in Figs. 7-4 through 7-12 represent typical cases and not a complete library of curves. From these curves,

* Trade name of Hercules, Inc.

† Trade name of Dow Chemical Co.

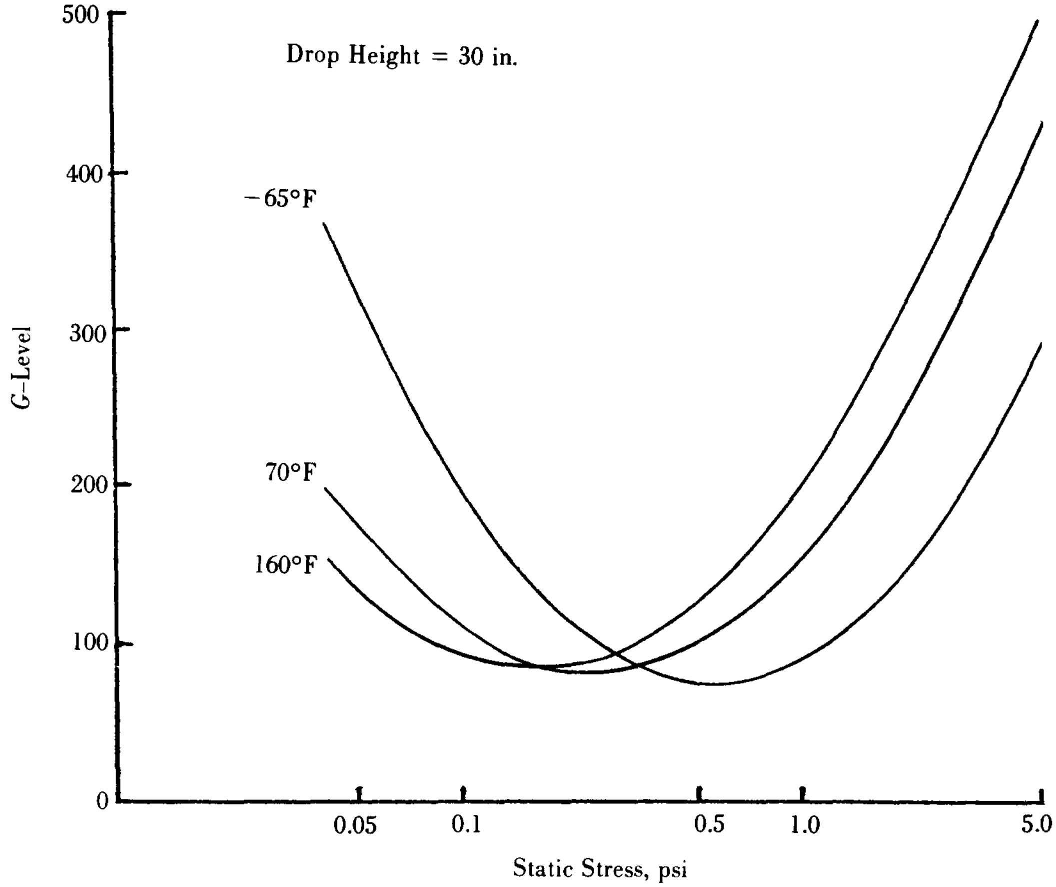



**Figure 7-4. One Inch of Minicel Superimposed Dynamic Cushioning Curves**

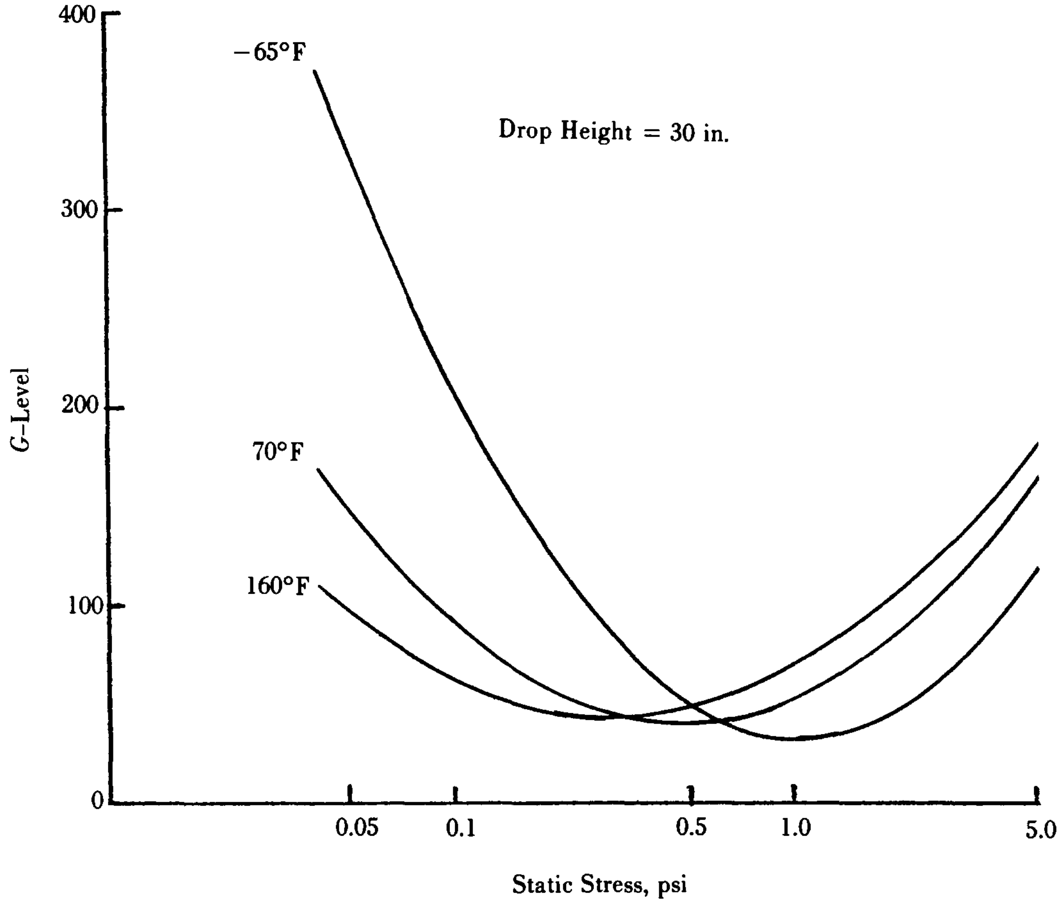



**Figure 7-5. Two Inches of Minicel Superimposed Dynamic Cushioning Curves**

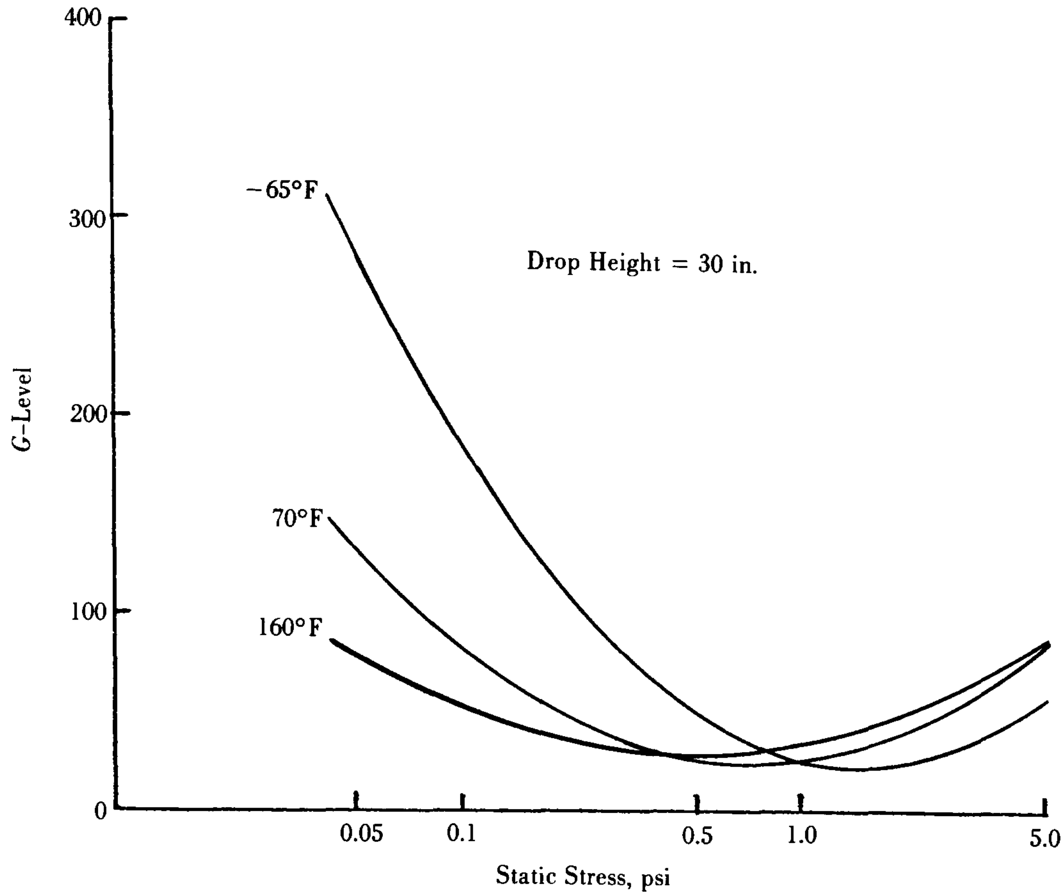



**Figure 7-6. Three Inches of Minicel Superimposed Dynamic Cushioning Curves**

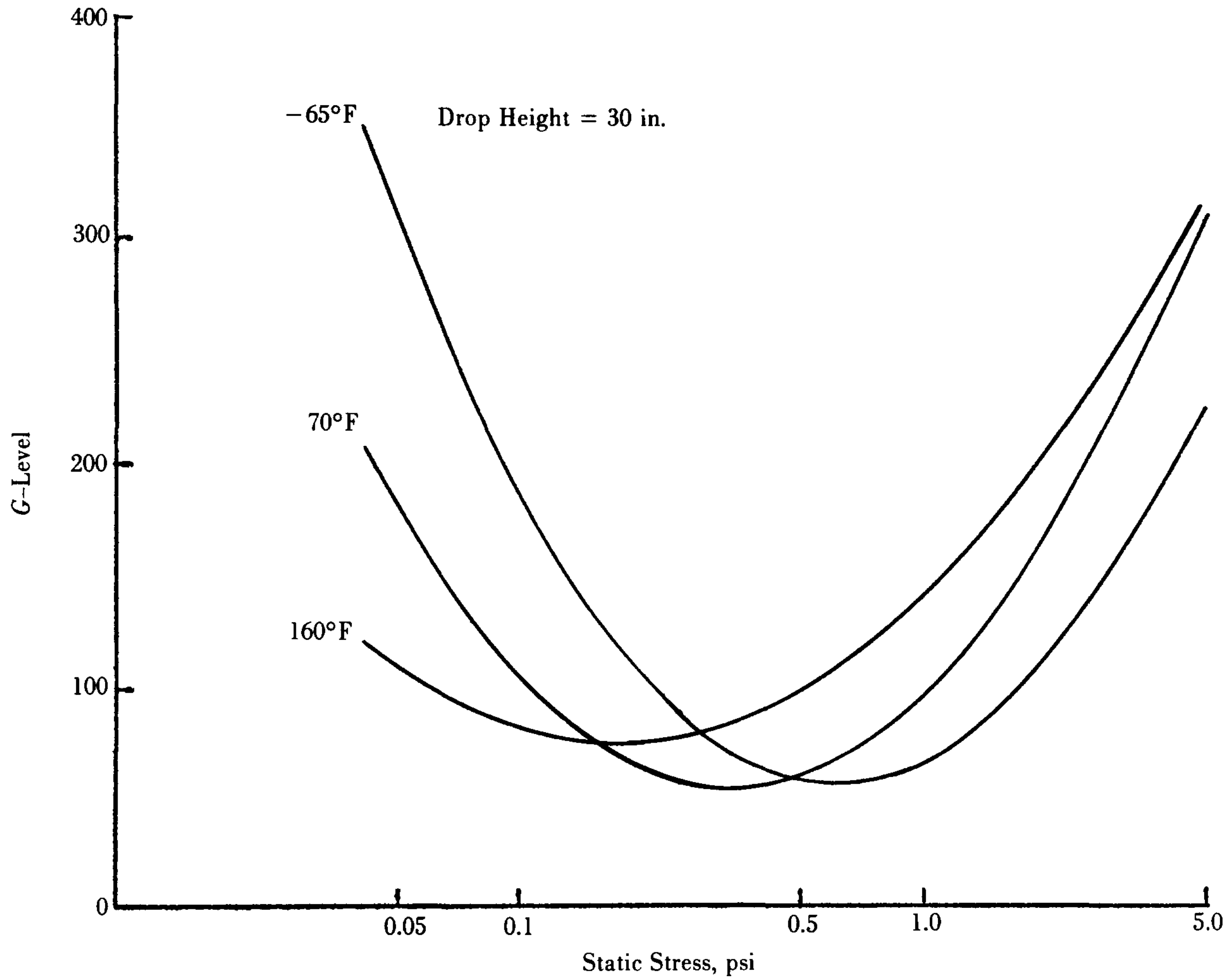



**Figure 7-7. One Inch of Ethafoam 2 Superimposed Dynamic Cushioning Curves**

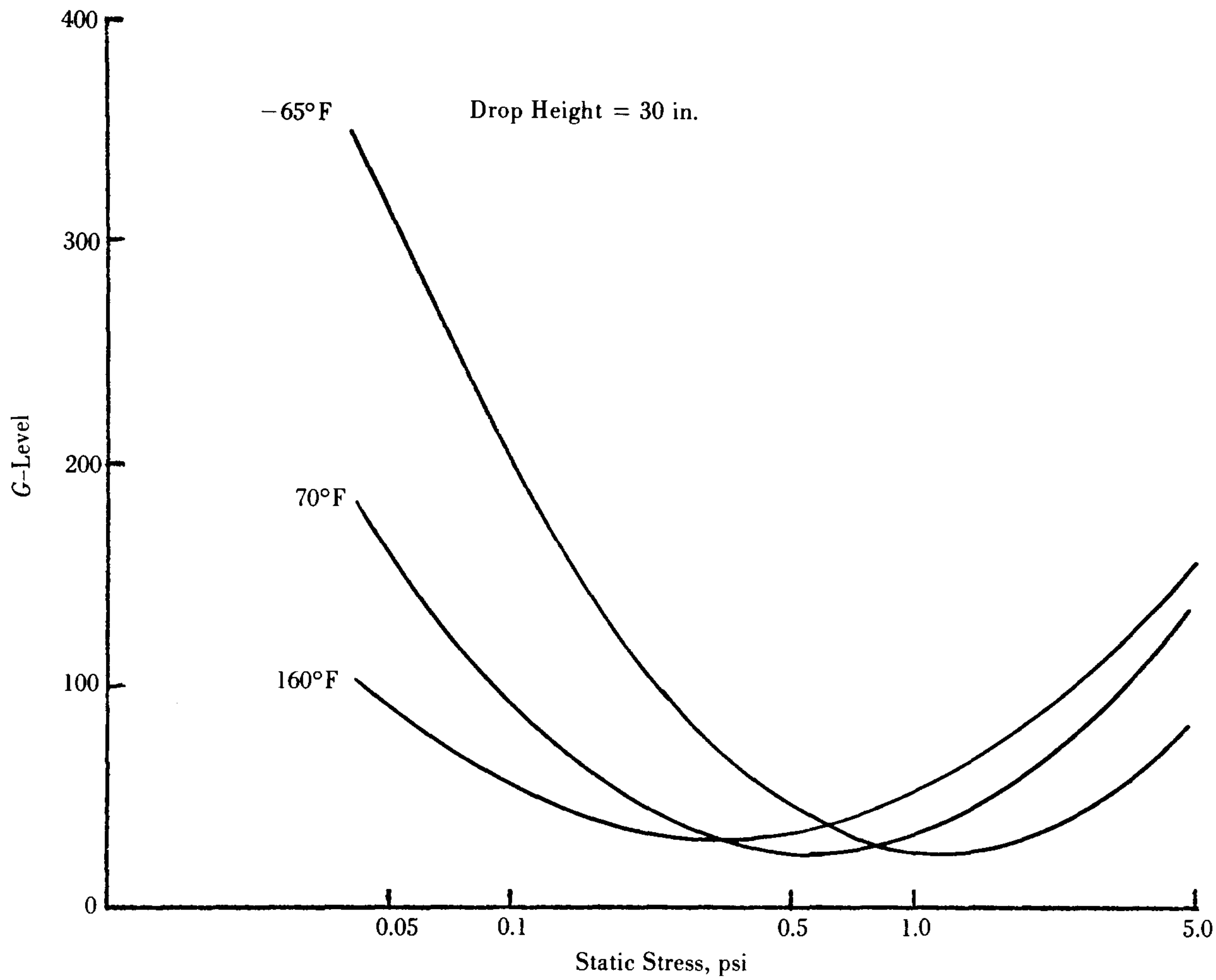



**Figure 7-8. Two Inches of Ethafoam 2 Superimposed Dynamic Cushioning Curves**

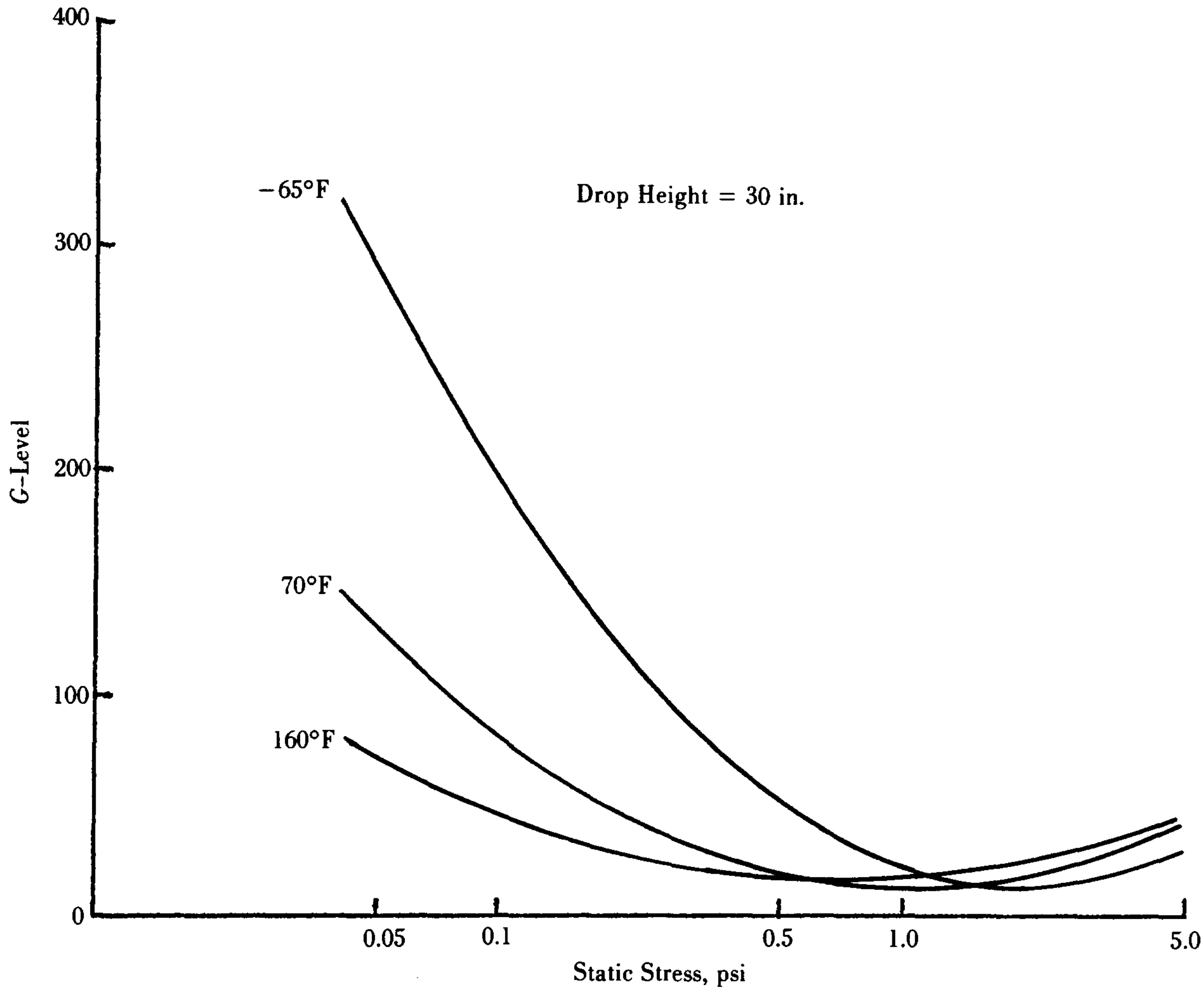



**Figure 7-9. Four Inches of Ethafoam 2 Superimposed Dynamic Cushioning Curves**

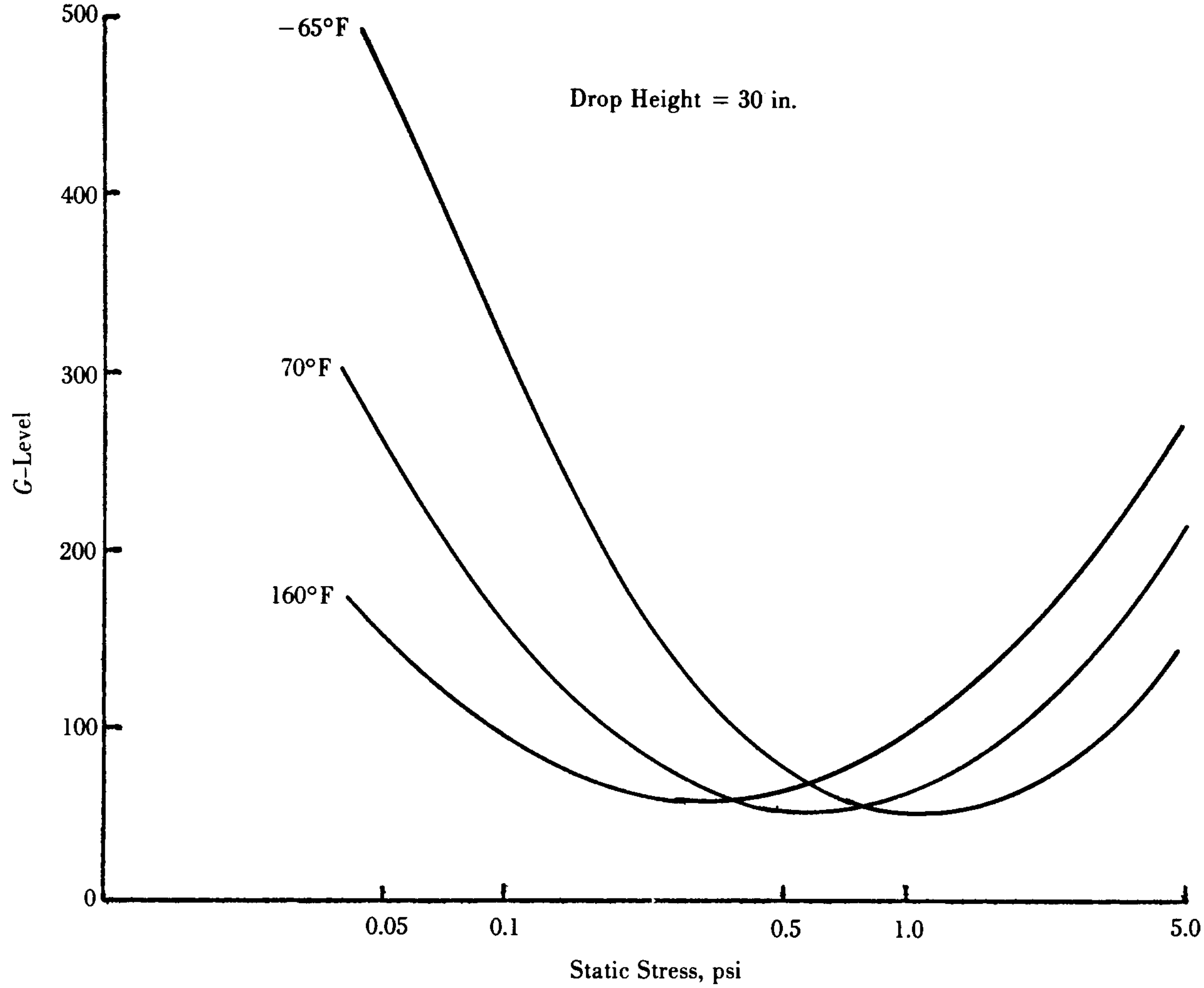



**Figure 7-10. One Inch of Ethafoam 4 Superimposed Dynamic Cushioning Curves**

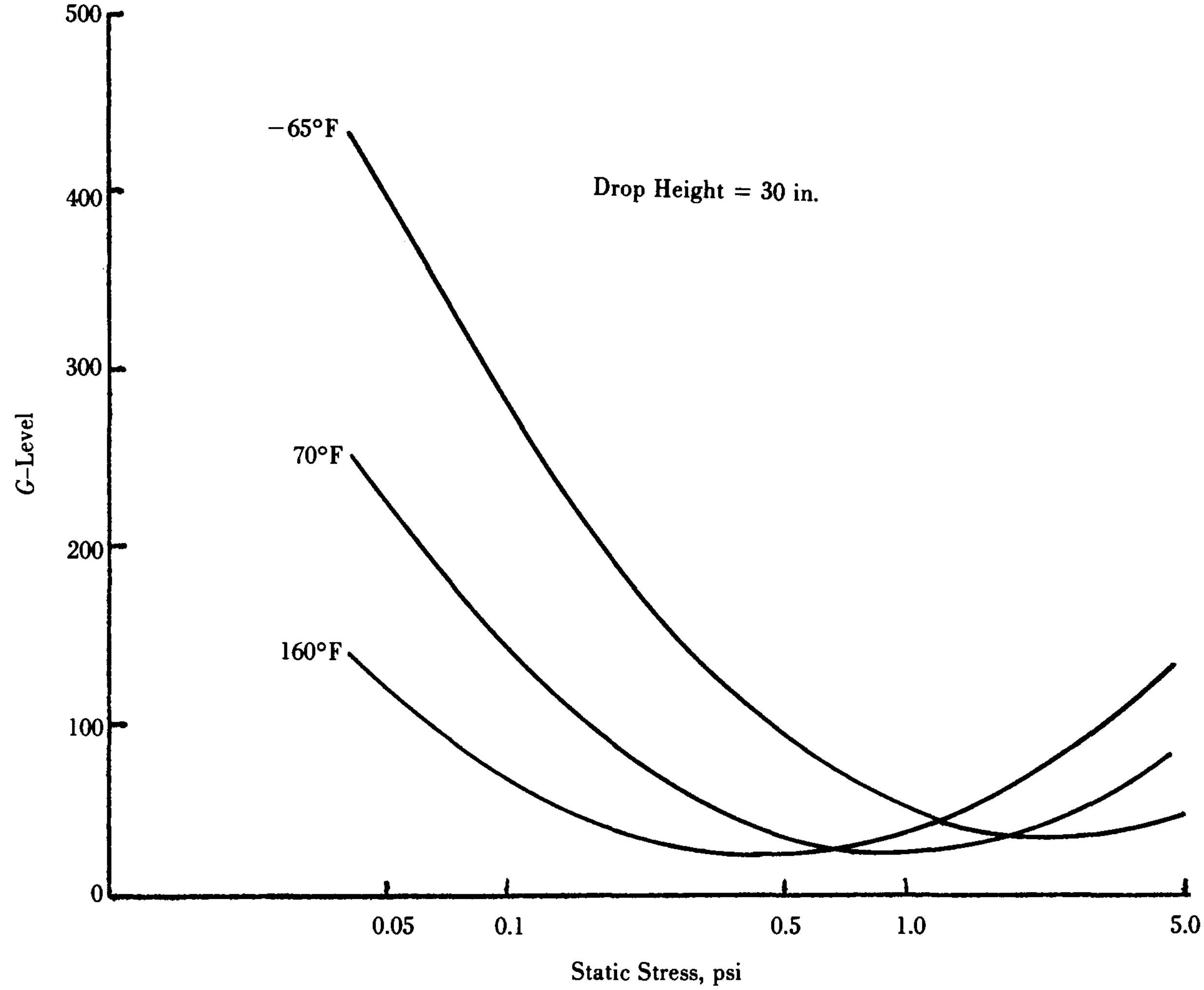



**Figure 7-11. Two Inches of Ethafoam 4 Superimposed Dynamic Cushioning Curves**

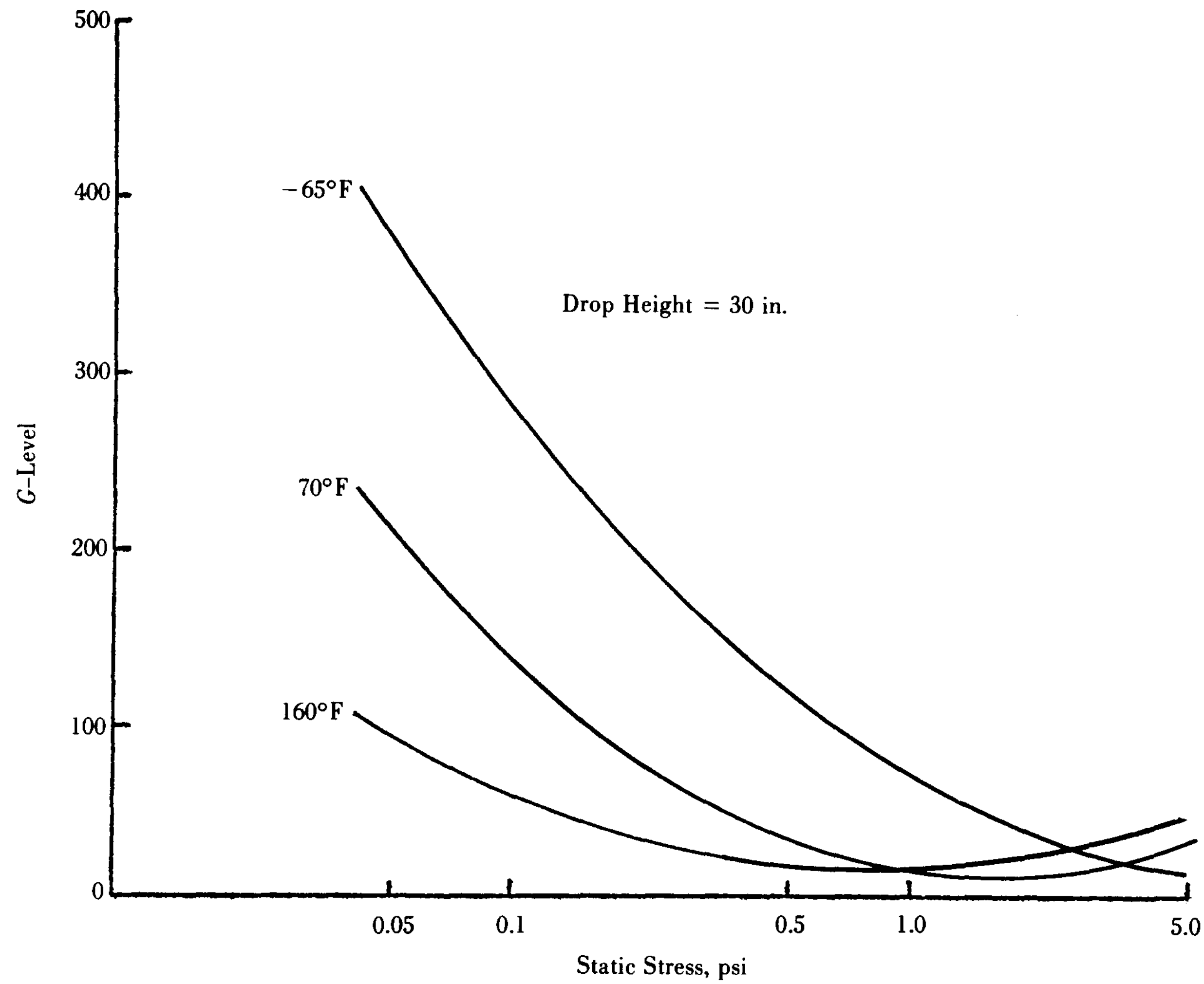



**Figure 7-12. Four Inches of Ethafoam 4 Superimposed Dynamic Cushioning Curves**

it is very obvious that temperature has a substantial effect upon the cushioning ability of a material.

### 7-3.2 URETHANE FOAM

Polyurethane foam materials have attracted considerable interest for military cushioning applications. These materials possess extremely versatile properties, permitting various formulations from extremely rigid to very flexible, within a wide range of densities. Polyester-based urethanes were the first urethanes to be developed. However, due to their relatively high cost, polyester urethanes are seldom used in cushioning applications. Polyether-based foams, however, are very cost-effective and are frequently used in cushioning applications. Polyether-based foams are made by reacting tolerance diisocyanate with polyglycol materials in a simple mixing operation.

A characteristic peculiar to polyurethane is its ability to be conveniently foamed in place to encapsulate items having complex configurations. In this situation, the item is positioned in the exterior container and the polyurethane foam is introduced, in a one-shot liquid form, into the cavity between the item and the container exterior wall and allowed to "foam up" and capture the item.

Superimposed dynamic cushioning curves are provided for the polyether-based urethanes at -20°F, +70°F, and +160°F; for thicknesses of 1, 2, and 4 in.; and a drop height of 30 in. in Figs. 7-13 through 7-15, respectively (Ref. 6). Similar information is provided for the polyester-based urethanes, under the same conditions as polyether, in Figs. 7-16 through 7-18 (Ref. 6).

### 7-3.3 RUBBERIZED HAIR

Rubberized hair is a commercially available bound fiber cushioning material which is comprised of latex-treated animal fibers, vulcanized to provide a bonded assembly. It is available in either sheet form or as a contoured mold. Although five types (densities) of rubberized hair are manufactured, only type IV and type V are sufficiently dense for use as military cushioning systems. Type IV may be used for loads up to 1.3 psi, while type V provides for loads up to 1.5 psi.

It should be noted that latex-treated animal fibers acquire a pronounced sulphuric property during the vulcanization process which may affect the integrity of silver-soldered joints. Other liabilities introduced by the latex which limit the application of rubberized hair include:

a. Tend to adopt a definite set of extended duration under shock load

b. Reliability below 32°F not yet established

c. Experience swelling after exposure to petroleum base substances

d. Develop a hard, brittle texture when exposed to prolonged direct sunlight

e. Become unreliable in the presence of certain oxidizers

f. Possess unsatisfactory flame resistance

g. Suffer loss in resiliency with age

h. Damping ability questionable within temperature range required for worldwide distribution.

In general, the dynamic compression characteristics of sheet-stock rubberized hair may be improved substantially by loading the pad in an edgewise direction as indicated by the data for 2-in. rubberized hair in Fig. 7-19. The data shown represent tests conducted with an impact velocity equivalent to a 30-in. drop height.

The increased efficiency of hair-on-edge pads tends to offset their higher cost. They should be considered for certain applications, especially when a range of static stress of about 0.10 to 0.25 psi is involved.

In addition to latex, additional chemicals are normally included which provide resistance to mold, rot, and fungus. Because of its porosity, rubberized hair provides for maximum air circulation and minimum moisture retention.

Since the reliability of rubberized hair at low temperatures has not been established, it is recommended that +20°F be considered as the lower limit until further tests either confirm or reject the validity of this lower temperature limit. Consequently, superimposed dynamic cushioning curves for type IV rubberized hair are shown in Figs. 7-20 and 7-21, respectively, for temperatures of +20°F, +70°F, and +160°F; thicknesses of 2 and 4 in.; and a drop height of 30 in. (Ref. 7). Figs. 7-22 and 7-23 are for type V rubberized hair with all conditions the same except the 4 in. thickness has been replaced by a 3 in. thickness (Ref. 7). As would be expected, rubberized hair is the least sensitive to temperature of all the cushioning materials for which superimposed dynamic cushioning curves have been provided. However, the limited temperature range over which it has been tested may have a significant effect upon this temperature sensitivity.

## 7-4 FACTORS AFFECTING CUSHIONING MATERIAL SELECTION

The selection of a cushioning material for a specific application considers a number of interrelated factors. These interrelated factors become critical after

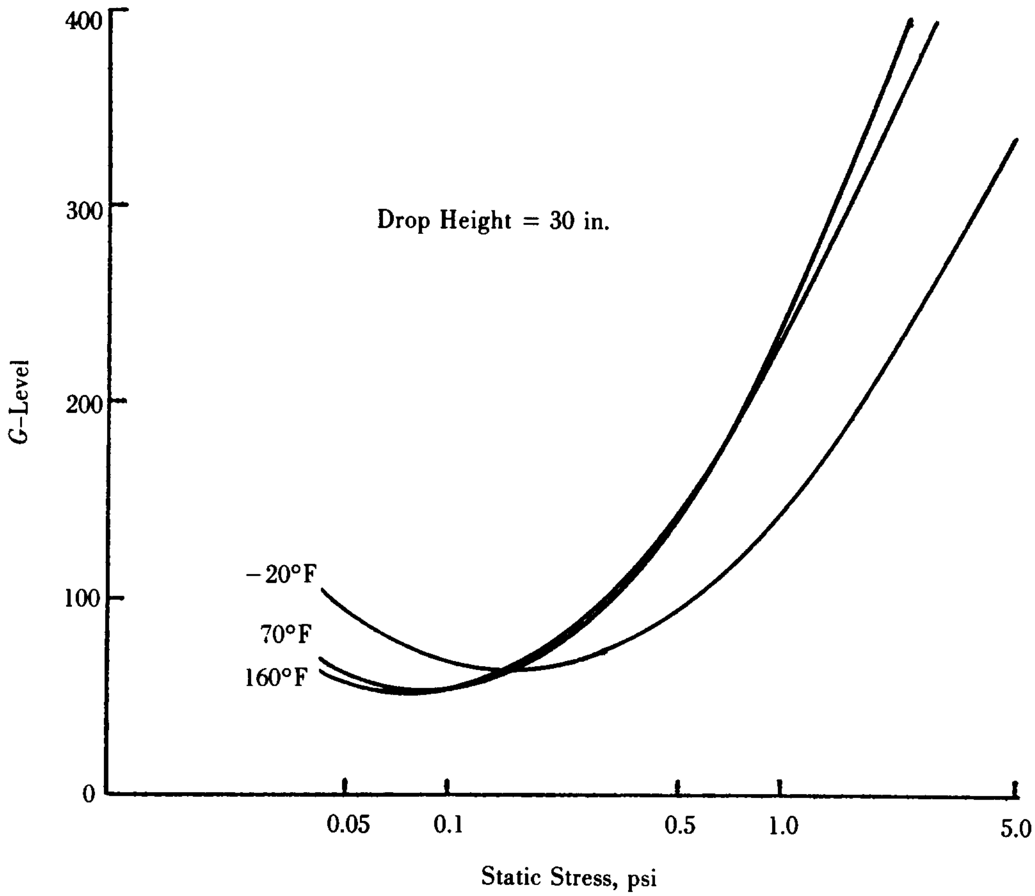



**Figure 7-13. One Inch of Urethane (Ether Type) Superimposed Dynamic Cushioning Curves**

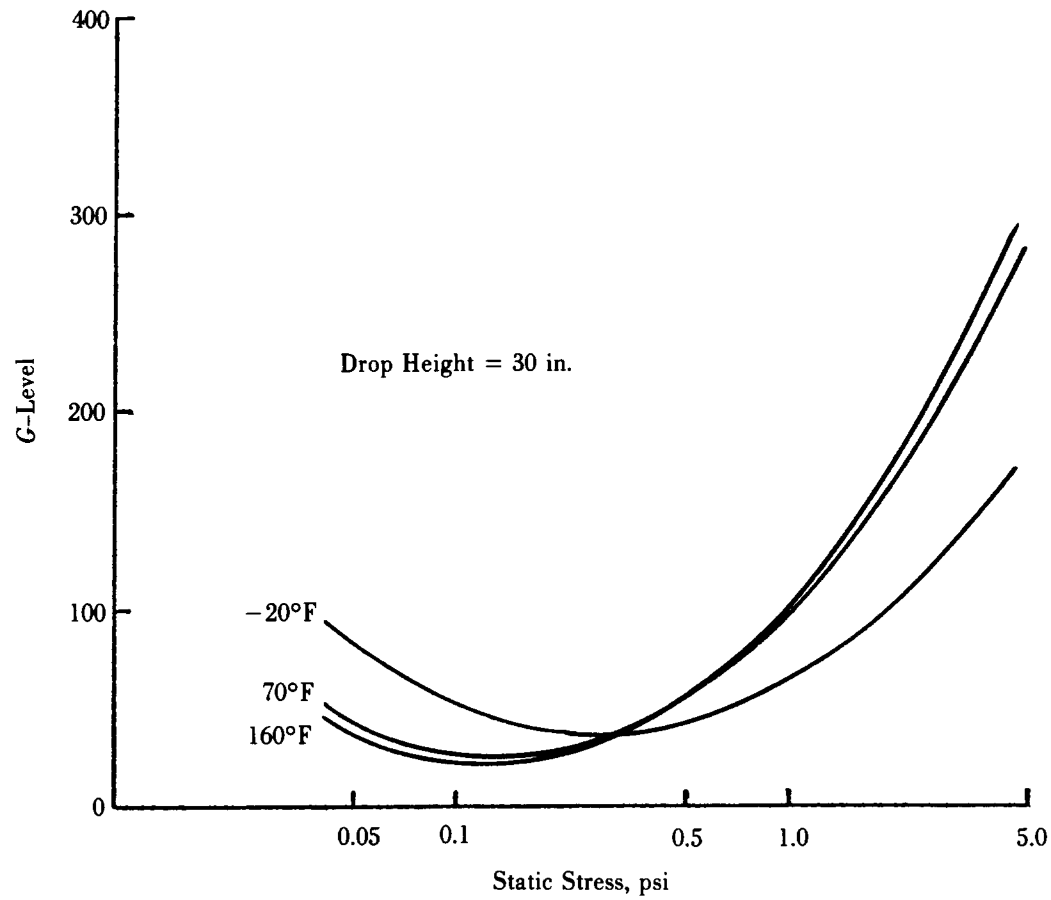



**Figure 7-14. Two Inches of Urethane (Ether Type) Superimposed Dynamic Cushioning Curves**

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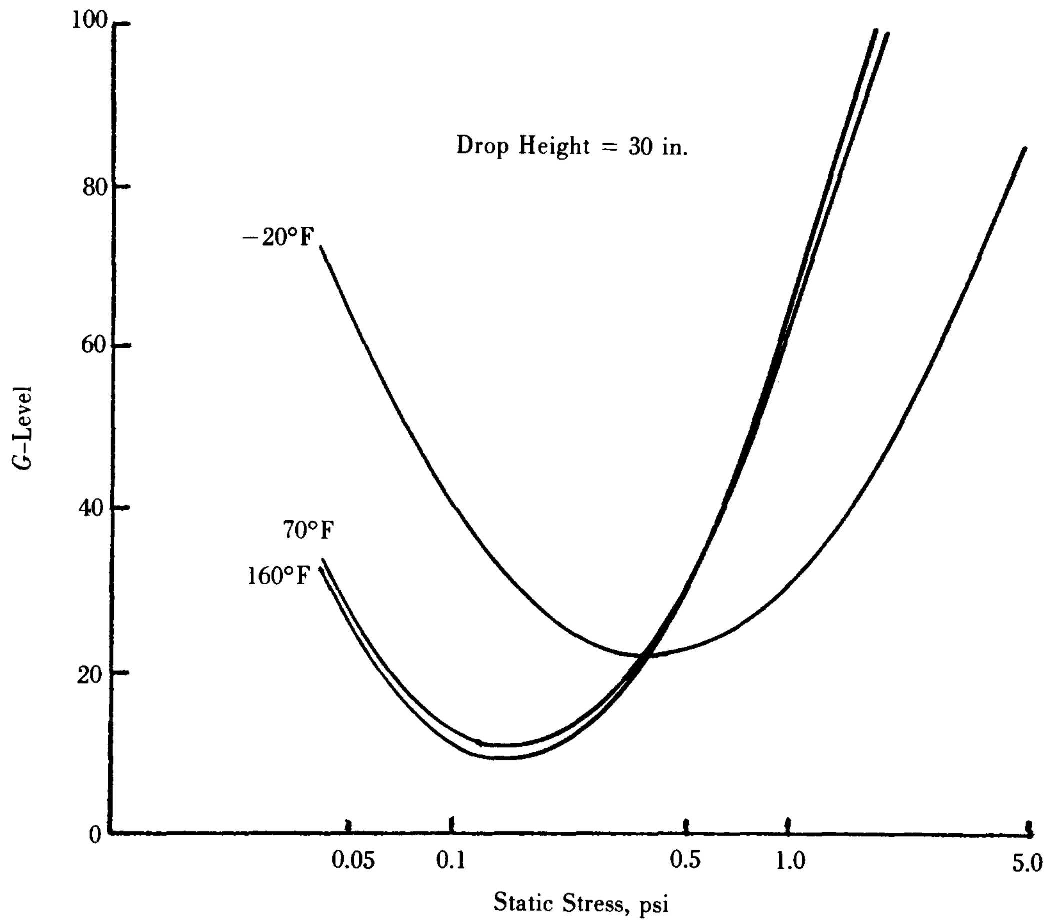



**Figure 7-15. Four Inches of Urethane (Ether Type) Superimposed Dynamic Cushioning Curves**

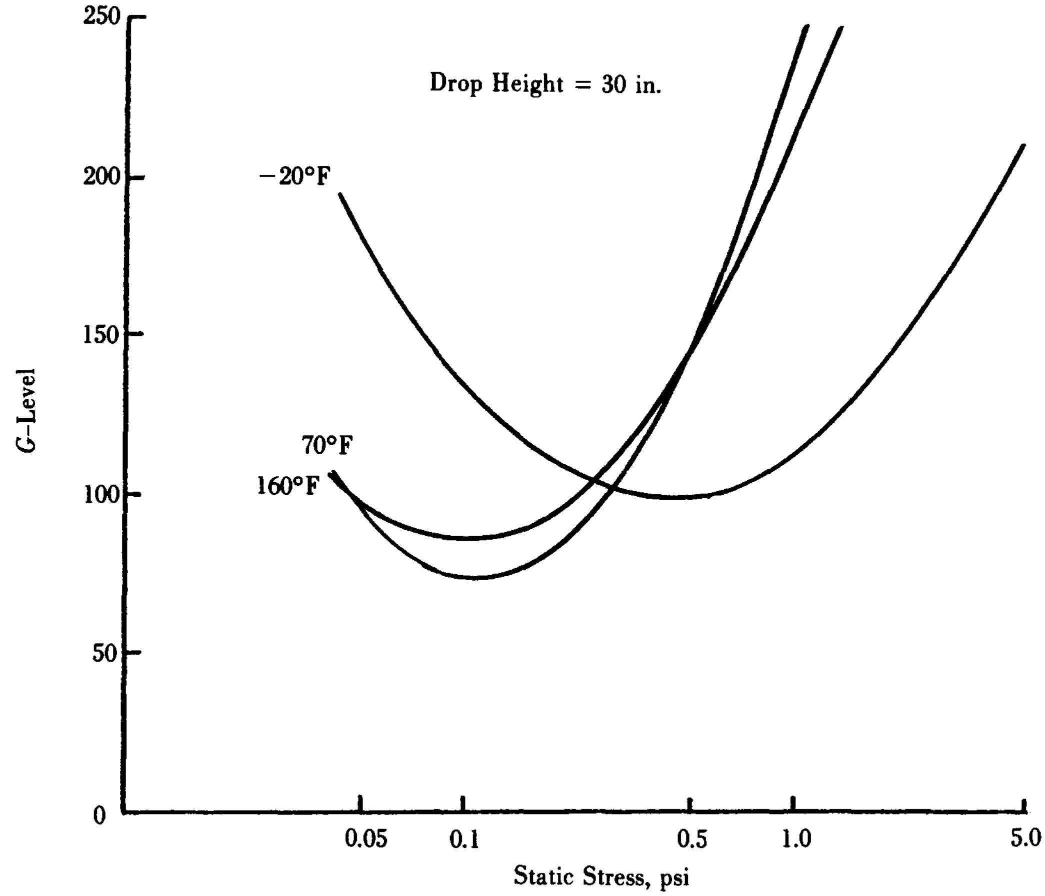



**Figure 7-16. One Inch of Urethane (Ester Type) Superimposed Dynamic Cushioning Curves**

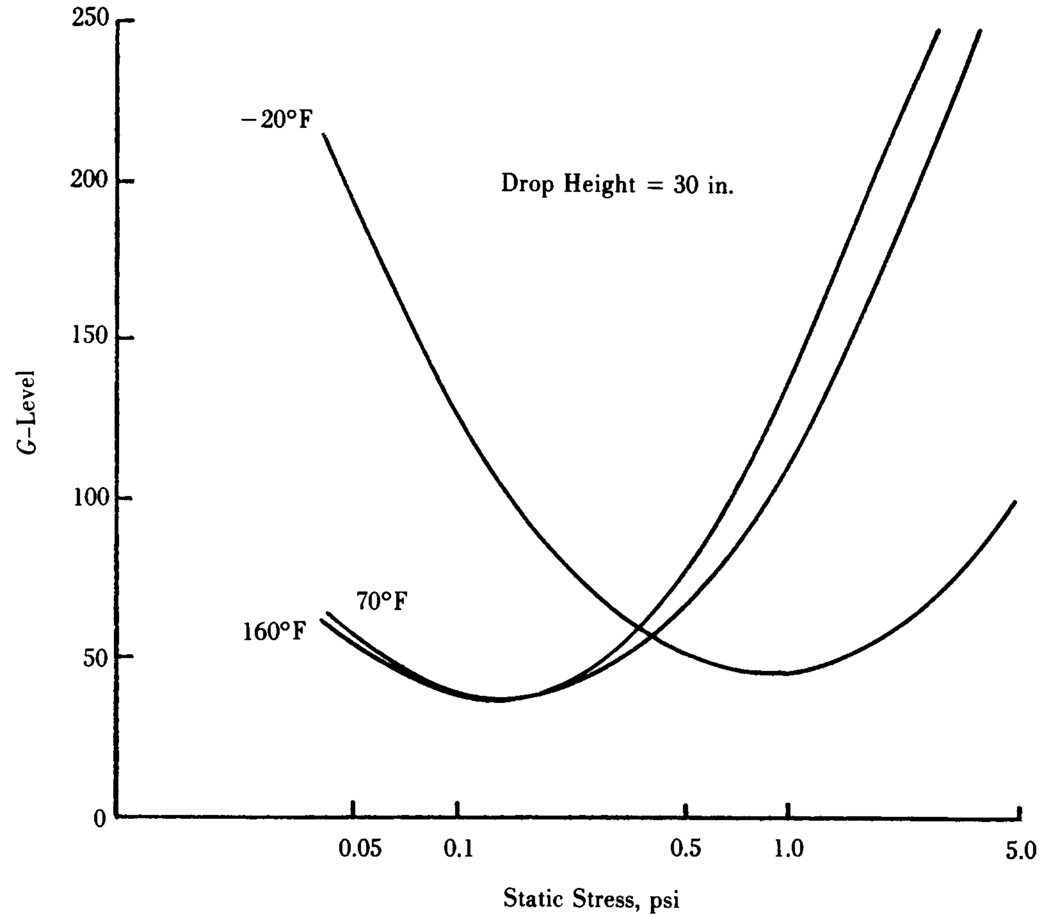



**Figure 7-17. Two Inches of Urethane (Ester Type) Superimposed Dynamic Cushioning Curves**

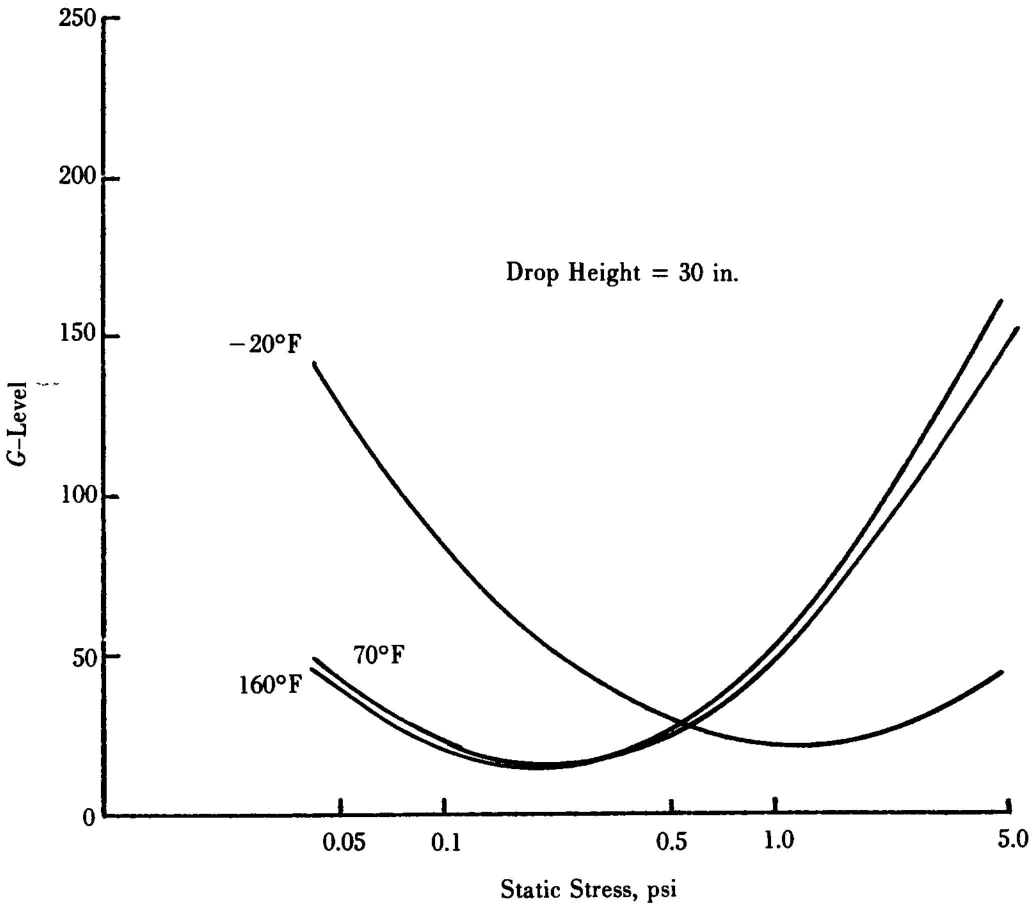



**Figure 7-18. Four Inches of Urethane (Ester Type) Superimposed Dynamic Cushioning Curves**

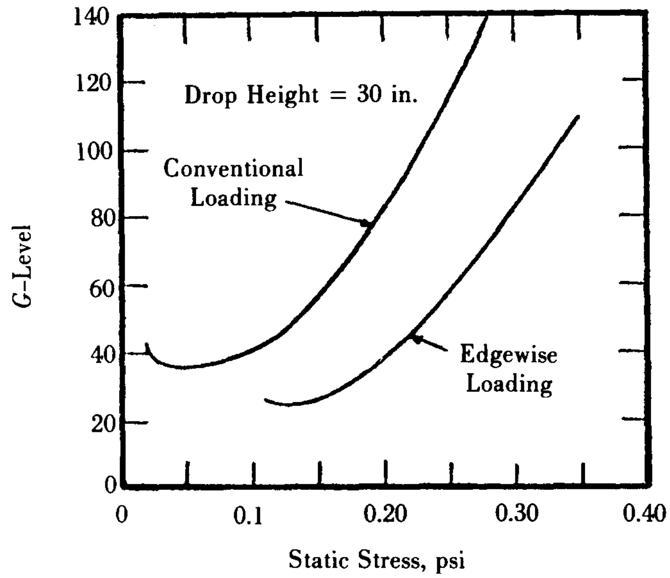



**Figure 7-19. Effects of Loading Orientation Upon Dynamic Compression Characteristics of 2-lb Density, 2-in. Thick Rubberized Hair**

preliminary cushioning decisions regarding the shock and vibration environments have been made.

### 7-4.1 ENVIRONMENTAL CONSIDERATIONS

The performance of most cushioning materials is adversely affected by exposure to high humidity and/or temperature extremes. Cushioning systems whose design has been based on general dynamic response data will ultimately fail when exposed to environmental extremes. The designer must be cognizant of this degradation of performance and compensate for the possibility of exposure to conditions other than 70°F. This weakness in cushioning system design is eliminated through the use of superimposed dynamic cushioning curves which consider the temperature extremes likely to be encountered.

Generally, low temperature exposure is considered to be the most severe of the extreme climatic conditions. At low temperatures, cushioning materials experience a loss of resiliency, become brittle, and subsequently fail.

Cushioning materials—having the capacity to adsorb, absorb, or retain moisture and/or water—will, when exposed to such conditions, experience degradation of physical response. Degradation of performance is further compounded should the relatively wet cushion be subsequently exposed to a subfreezing temperature. Materials not resistant to moisture penetration must be contained within sealed barriers or coated to provide the necessary moisture resistance.

The dimensional stability of thermoplastic compounds will be affected by exposure to high temperatures and, through loss of restraint, will degrade the protective charcteristics of the cushion system.

### 7-4.2 COMPRESSION SET

Cushioning materials vary in their inherent ability to recover original thickness upon removal of an applied load. This deviation from perfect recovery (100% of original thickness) is referred to as "set" and when caused by compressive load is expressed as "Compression Set". Loads peculiar to the environment of worldwide distribution subject cushioning to compressive forces resulting in set. This dimensional deformation is the result of:

a. Long-term static storage

b. Dynamic shock forces resulting from rough handling

c. Forces generated by the transit media vibrational inputs.

Compression set is undesirable in cushioning material for two principal reasons:

a. Looseness (and the related increased likelihood of damage)

b. With some cushioning materials it indicates that the compressive stress-strain behavior of the material has changed and that the possibility of damage caused by "bottoming" has also increased.

Some effects of looseness in a package are depicted by Fig. 7-24 where:

a. Fig. 7-24(A) represents a cushioned item being displayed normally from its original position during a drop against a flat, rigid surface.

b. Fig. 7-24(B) illustrates the same item in a different position due to jostling and looseness and, therefore, it receives an impact on a point.

c. Fig. 7-24(C) represents a loosely packaged item moving in a direction opposite from that of the exterior container and cushioning.

The instance of Fig. 7-24(C) could occur during vibration of the package as it rests on the bed of a truck or rail car. The vibration causes larger peak forces and accelerations to be developed and these, in turn, increase the likelihood of damage to the item.

Compensation for compression set is usually accomplished by:

a. Designing according to data that have involved a realistic amount of preworking prior to testing and repetition of impacts, or

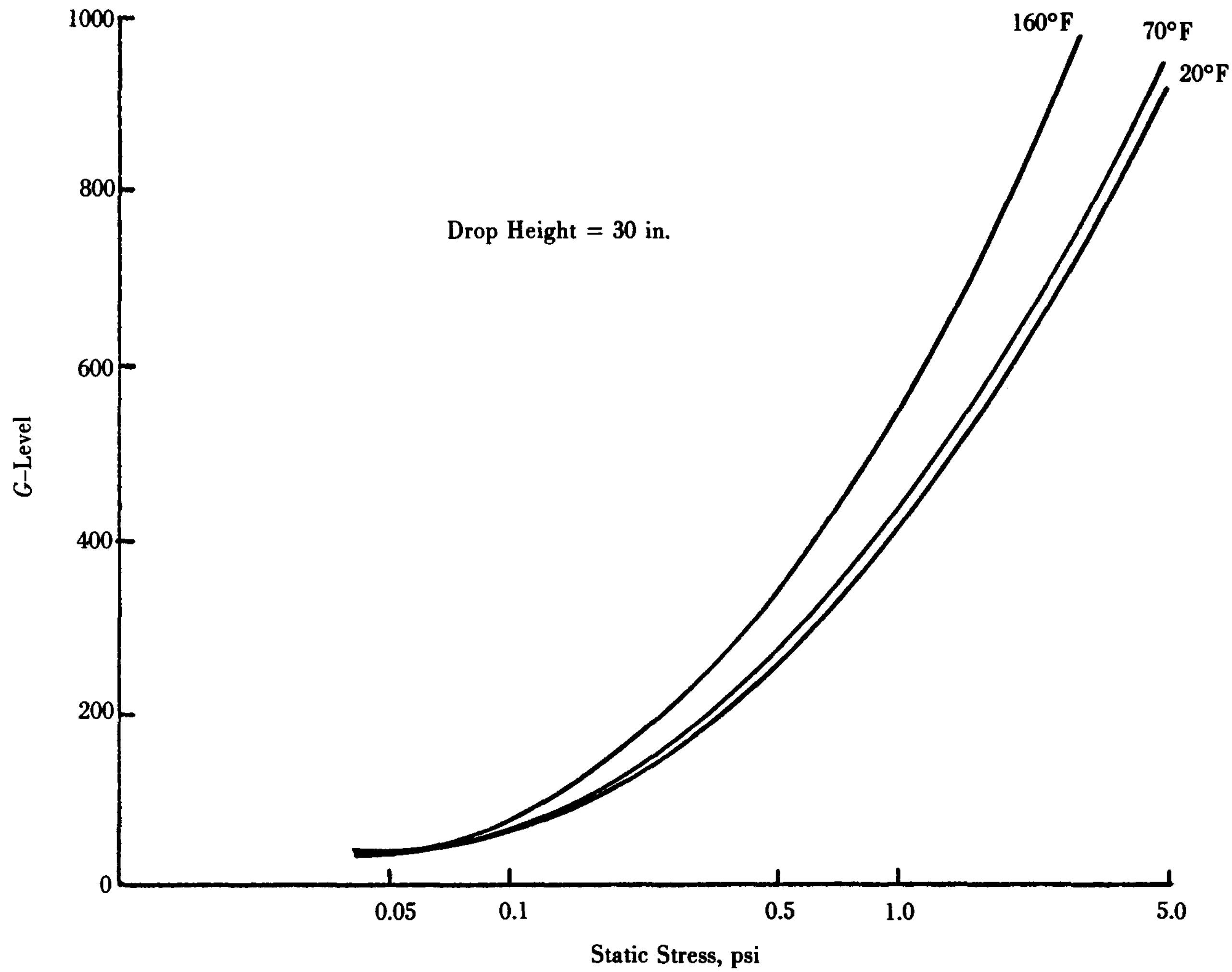



**Figure 7-20. Two Inches of Rubberized Hair (Type IV) Superimposed Dynamic Cushioning Curves**

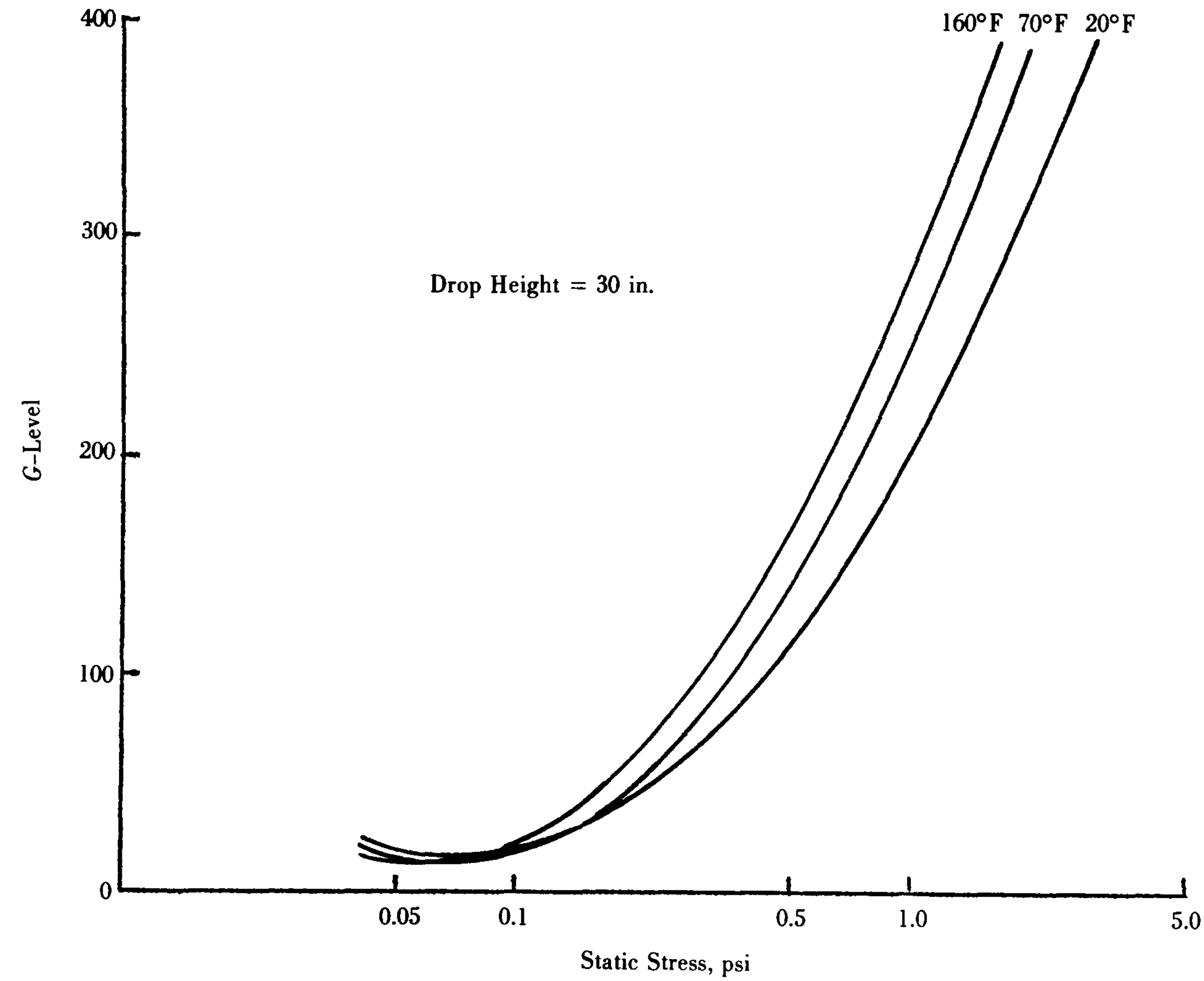



**Figure 7-21. Four Inches of Rubberized Hair (Type IV) Superimposed Dynamic Cushioning Curves**

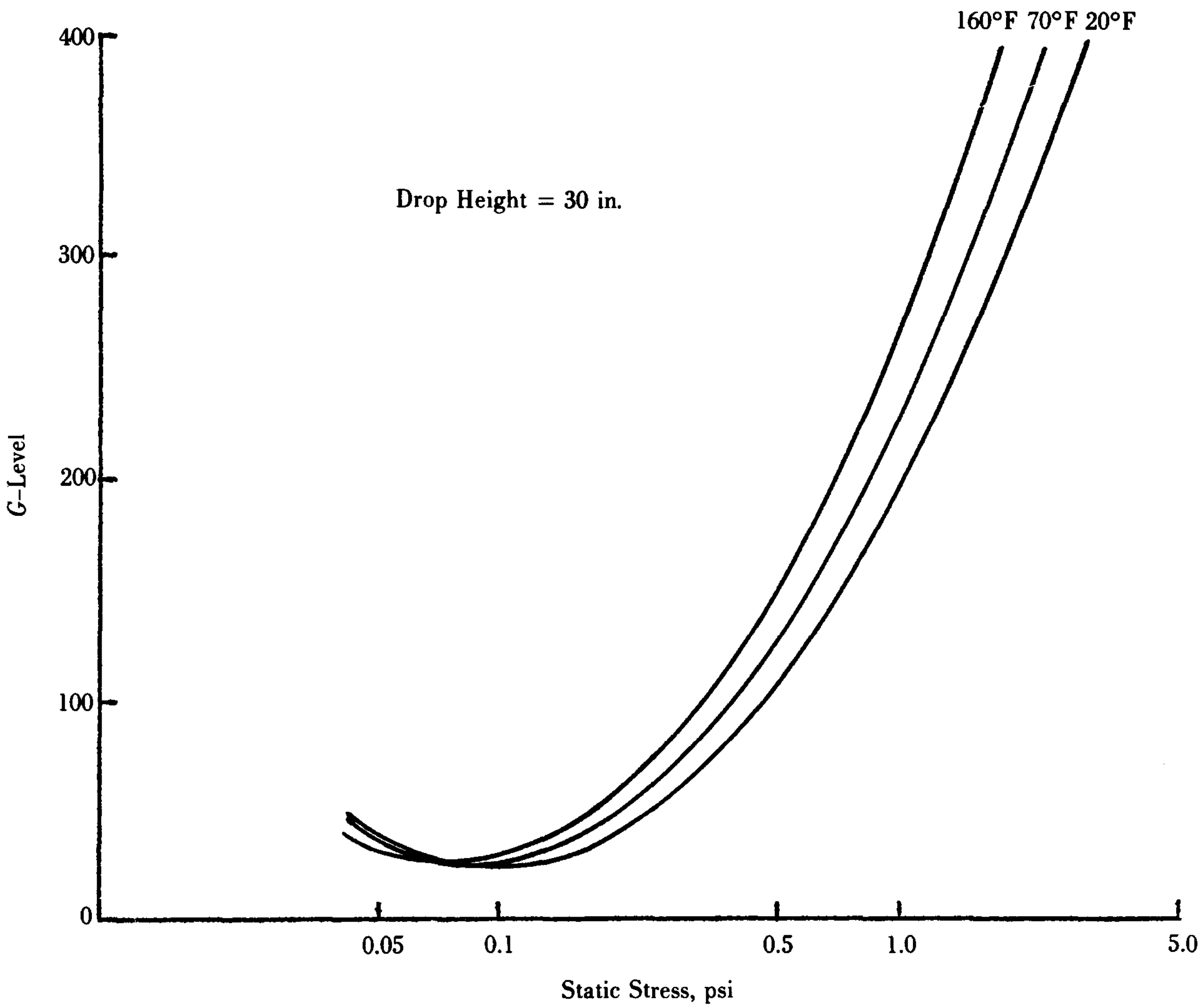



**Figure 7-22. Two Inches of Rubberized Hair (Type V) Superimposed Dynamic Cushioning Curves**

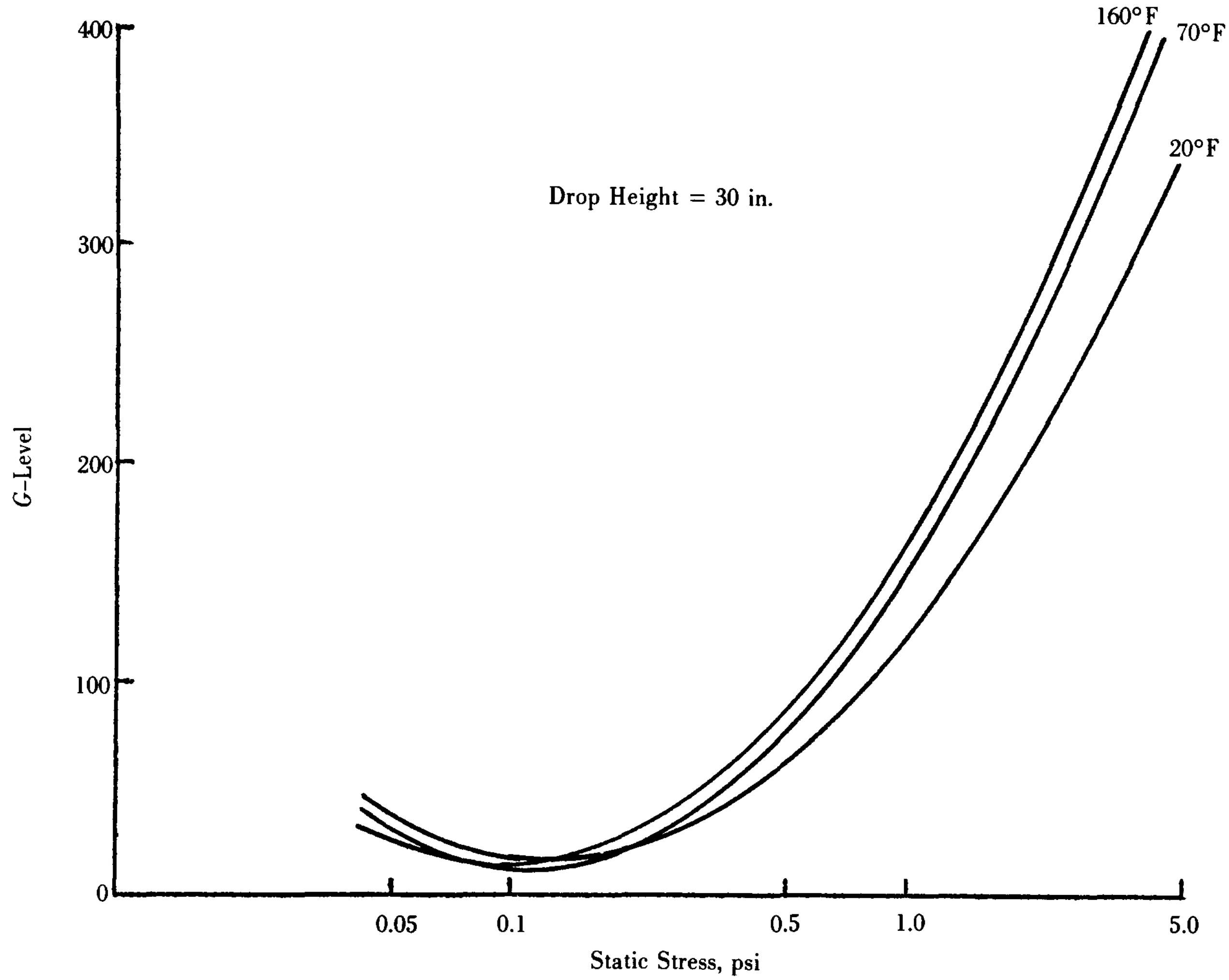



**Figure 7-23. Three Inches of Rubberized Hair (Type V) Superimposed Dynamic Cushioning Curves**

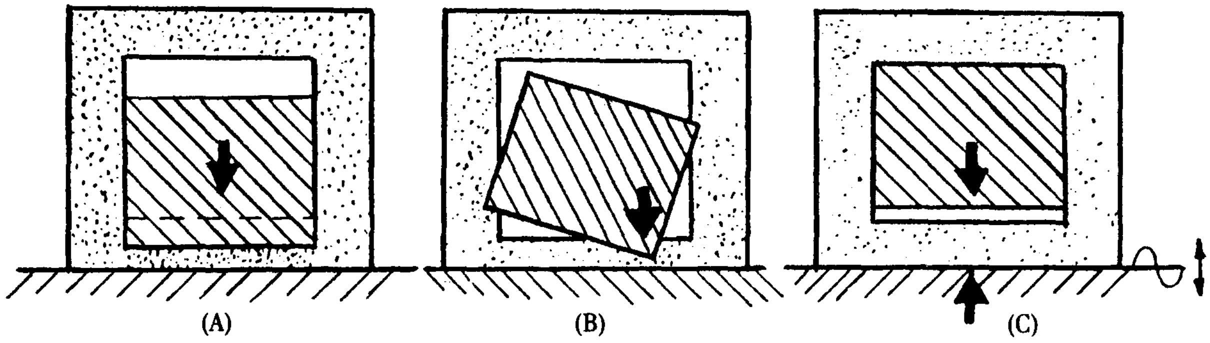



**Figure 7-24. Effects of Looseness in a Package**

b. Applying an excess of cushioning material in precompressed condition (usually accomplished indirectly when such compensation is made for creep).

### 7-4.3 CREEP

Virtually all cushioning materials, when subjected to a constant load for a period of time, tend to lose thickness; this phenomenon is referred to as "creep". The creep rate for all common package cushioning materials is greatest at initial loading and declines exponentially with elapsed time thereafter. After a load is removed, a cushion will regain most of its original thickness, but some permanent set will have been produced. Therefore, to prevent looseness in packages, it is desirable to apply an extra thickness of cushioning material (in a precompressed state) in the package. However, because of the difficulty of closing a container after insertion of precompressed cushions, their use to offset creep is practicable only if relatively light precompression forces are required.

The amount of extra cushioning thickness required to offset creep can be estimated arbitrarily as

$$T_c = T + T/3 \tag{7-1}$$

where

$T_c$ = thickness of cushioning material required to compensate for creep

$T$ = thickness of cushioning material required without considering creep

or, preferably, be calculated using available creep-time data. Creep-time curves are generally unavailable for the commonly used ranges of static stress; however, should they be or when they do become available, they should be used in preference to the arbitrary value of 1/3.

Regardless of the method used, it is customary to add extra thickness to either the top or bottom cushion—but not both.

### 7-4.4 BUCKLING

Long, slender cushions whose height is proportionately greater than its least lateral dimension will function as a column and have a tendency to buckle when axial forces are applied. Columnar buckling precedes any compression which may occur and negates the protective characteristics of the cushion. This condition, depicted in Fig. 7-25, is most undesirable and may result in damage to the protected contents.

The stability of a cushion pad is dependent upon the ratio of its physical characteristics; this relationship has been established as follows:

a. A cushion will not buckle if:

$$\frac{\sqrt{A}}{T} \geq 1.33 \tag{7-2}$$

where

$A$ = cross-sectional area of pad

$T$ = thickness of pad

and $A$ and $T$ are expressed in identical units.

b. The minimum bearing area $A_{min}$ per cushion required to prevent buckling is

$$A_{min} = (1.33T)^2. \tag{7-3}$$

Care must be exercised in the application of Eqs. 7-2 and 7-3 when corner pads are used. Each corner pad is considered to be an individual cushion, and any calculations associated with buckling must obey this basic premise.

### 7-4.5 PNEUMATIC EFFECTS

Recent studies (Ref. 8) conducted by MICOM have shown that there is a considerable difference in

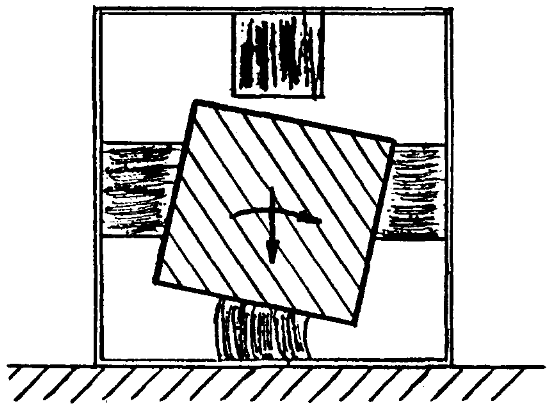


**Figure 7-25. Columnar Buckling of a Cushion**

the dynamic properties of cushioning between the "unconfined" and "confined", or "as packaged" states. Confined and unconfined dynamic drop tests are conducted on like specimens of cushioning materials of known density and size, and under comparable environmental conditions. From these data, static stress versus *G*-level curves are plotted as shown in Fig. 7-26. It can be seen from this figure that:

1. Beyond the optimum loading range, the *G*-level transmitted by the unconfined cushion begins to rise.
2. The curves are noted to be closest together near the optimum loading value for the unconfined data.
3. The confined curve does not increase in *G*-level value as rapidly as the unconfined curve.
4. The confined curve indicates that greater protection is being offered the protected item since the *G*-level values are lower than for the unconfined data. This indicates that the outside container has absorbed some of the original shock, rather than transmitting all of this shock to the protected item.
5. The confined curve optimum loading value is to the right of the similar point on the unconfined curve. This phenomenon is a function of shock-time delay together with pneumatic effects within the container itself.

The use of dynamic unconfined data in the design of confined cushioning systems will provide a conservative solution. However, when a sealed outer container is used, the actual *G*-level values encountered will differ substantially from the unconfined data predictions.

### 7-4.6 FUNGOUS RESISTANCE

Many applications require the use of cushioning materials inert to the effects of fungi; however, while materials resistant to fungi are available, they should not be used indiscriminately. Practically, any cushioning material can be made resistant to fungi. The treatment usually involves impregnation of the material with a salt which may introduce undetectable corrosive elements.

### 7-4.7 HYDROGEN ION CONCENTRATION (pH)

The pH of the aqueous extract of cushioning materials has been considered traditionally to be somewhat of an indication of the inherent acidity and, therefore, the corrosiveness of the materials. Although the pH value for this purpose is questionable, no better practical test of corrosiveness of cushioning materials has been developed so far. Therefore, this test is frequently specified for quality control purposes in cushioning specifications. A pH rating of 7.0 is considered to be "neutral", i.e., neither acidic nor basic. However, the fact that a pH test indicates the aqueous extract of a material is 7.0 does not necessarily indicate that the material, when placed next to a ferrous metal in the presence of moisture or a humid atmosphere, will not cause corrosion.

### 7-4.8 ABRASIVE QUALITIES

Two aspects of abrasion relative to cushioning materials concern the container designer:

a. The inherent abrasiveness of the component material in cushion materials themselves

b. The capability of cushioning materials to prevent abrasion of the item by rough surfaces or projections of other objects (staples, surfaces or crate members, impinging corners of exterior containers of nearby packages, etc.).

Currently, no generally accepted test for the abrasion prevention capability of cushioning materials exists. One formidable obstacle deterring the development of such a test method is that little is known about the nature of the abrasion hazards of service on which such a test must be based.

The amount of material required to prevent abrasion must be selected according to past shipping records, sound judgment, and common carrier regulations.

### 7-4.9 TENSILE STRENGTH AND FLEXIBILITY

Minimum tensile strength and flexibility are customarily prescribed in cushioning material specifications to insure that the materials will not fail during normal handling and application.

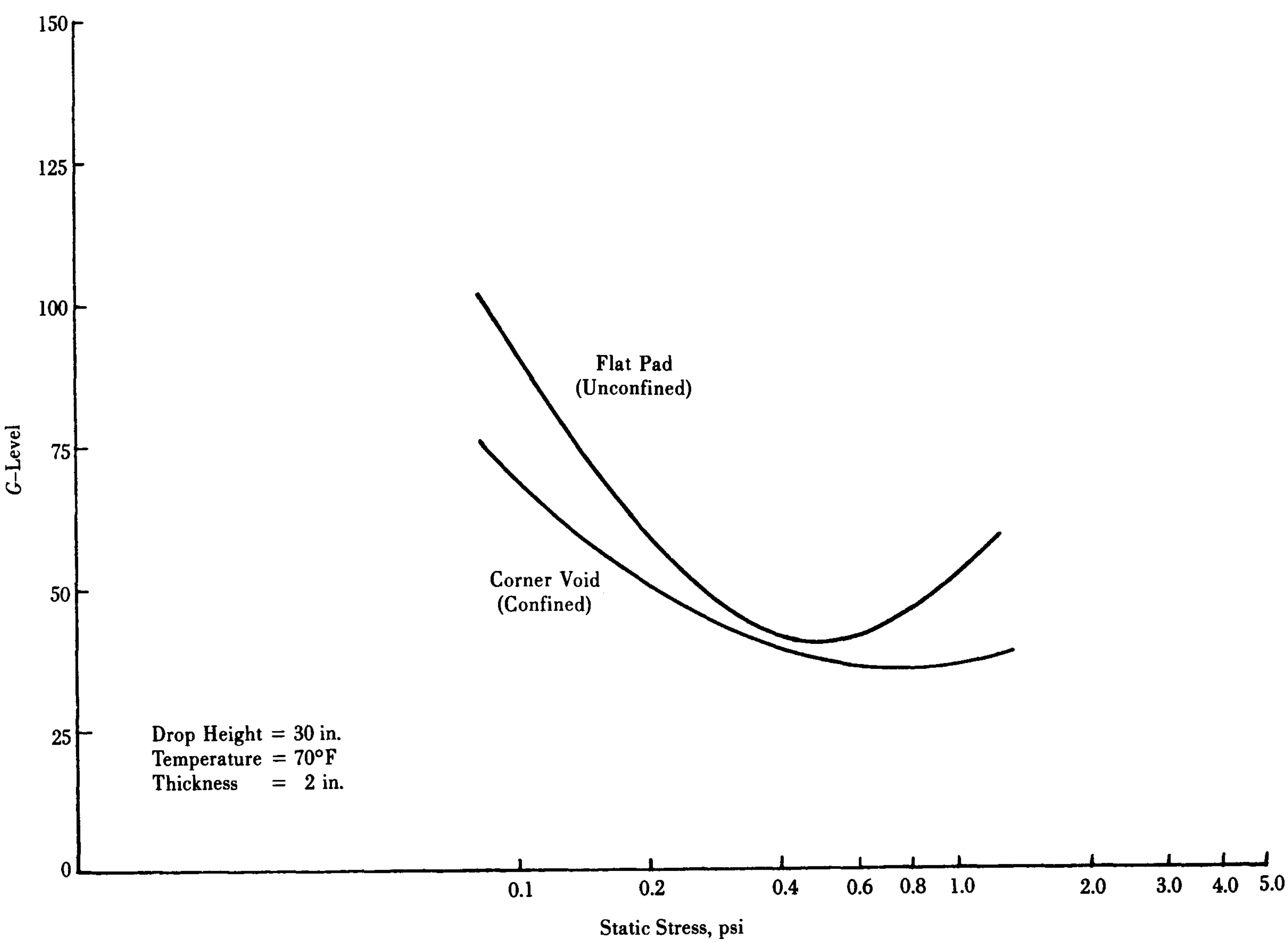



**Figure 7-26. Confined vs Unconfined Dynamic Cushioning Curves for Minicel**

### 7-4.10 DUSTING AND FRAGMENTATION

Despite large differences in their composition, all cushioning materials, if subjected to rough handling, will release some fragments. Although further study is needed, some investigators have reported that many cushioning materials when vibrated under maximum static load will disintegrate. It is strongly recommended when the container is tested that it be vibrated with its cushioning system under static stress loading.

Even if failure of the cushioning is not catastrophic, the liberation of a large number of fragments inside a package is objectionable because these particles tend to work into remote interstices which causes possible damage and/or requires considerable cleaning labor before the item is usable. Outside a package, the liberation of such particles may constitute a nuisance, both as litter and airborne particles.

## 7-5 APPLICATION TECHNIQUES

The effective and efficient use of bulk cushioning is dependent upon the configuration of the supporting pad and the strategic distribution of the material. The geometry of the protected item and the spatial limitations imposed by the container limit and restrict the latitude of design; however, regardless of these limitations, the performance of the cushion is largely dependent upon the ingenuity and proficiency of the designer.

Based on the recommended design procedure presented, it may be assumed that the proposed application has been analyzed and that the optimum cushioning material has been selected. The designer has identified the following:

a. The best material for the specific application

b. The dynamic characteristics of the material (static stress versus $G$-level)

c. The minimum cushion deflection required to mitigate the imposed shock $G$ to within the fragility level $(GL)_{max}$ of the item

d. The identification of accessible bearing points capable of supporting the suspended item.

The designer must next develop a suspension system which will:

a. Support and physically restrain the suspended item

b. Position and locate the cushion to engage those item bearing points capable of withstanding the developed static stress (psi)

c. Not result in a static stress outside the optimum working stress range of the cushion material

d. Not jeopardize or compromise the technical and economic aspects of the application.

It becomes evident that the developed stress imposed upon the cushion determines its protective qualities. Since stress $W/A$—where $W$ is the weight of the item and $A$ is the contact area—is a function of the area of contact, the applied load generally being considered constant, the designer must select those bearing points which will provide an adequate contact area. He then uses only as much of this area as is required in order to stay within the optimum working stress range of the superimposed dynamic response curve encompassing the pertinent $(GL)_{max}$ of the item to be protected.

The paragraphs that follow provide guidance to assist the designer in the development of a cushioning system to satisfy the criteria of both technical and economic feasibility. Several different configurations on the use of cushioning materials in actual practice are presented.

### 7-5.1 ENCAPSULATION

The simplest method of item cushioning is encapsulation. Sheet stock or blankets are used to engage the overall peripheral area of the protected item. The cushion thickness must be sufficient to mitigate shock to within the required protective level. The stress imposed upon the cushion by the protected item determines the density of the material used. The amount of cushion used normally is governed by the size of the container cavity and the need for physical restraint. Unless the container body can be tailored to the minimum cushion requirements, this method results in an excessive use of material. Fig. 7-27 illustrates the basic encapsulation concept for a square item.

The cushioning of irregularly shaped items often presents special problems, particularly when fragile projections are involved. A primary requisite is that an adequate thickness of cushioning must be provided to prevent bottoming of projections. Therefore,

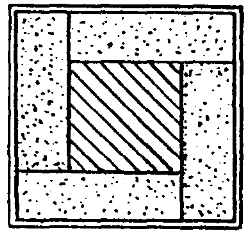
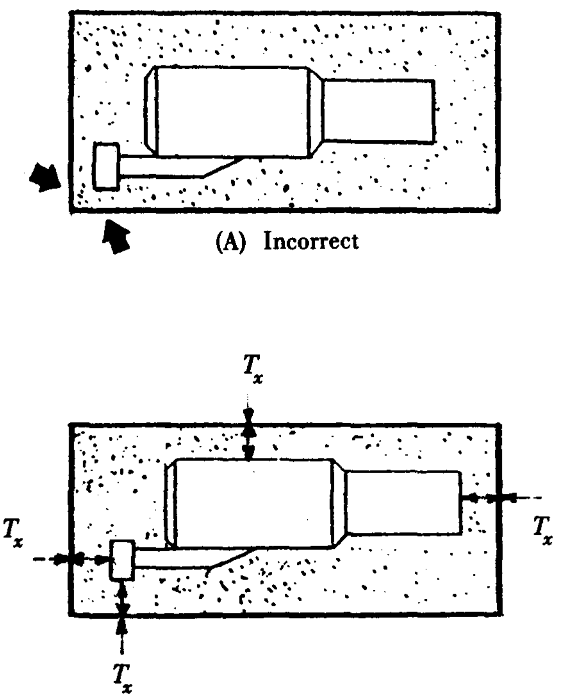


**Figure 7-27. Encapsulation**

the thickness of material to be provided must be measured from the outer container to the outermost projection—not to the item proper. Unfortunately, the effect of projections in reducing the effective thickness of cushions is often overlooked, especially in the production of molded cushions. This practice is illustrated in Fig. 7-28 where the required thickness of material to protect all sides of the hypothetical item shown is represented by $T_x$.




(B) Correct

**Figure 7-28. Cushioning of an Item With Projections**

Molded pads can be manufactured to fit and protect almost any item regardless of shape or size. A typical example of a pack employing molded pads is shown in Fig. 7-29. Such pads are usually custom designed and produced by the cushioning manufacturer.

In addition to being well suited to packaging of irregularly shaped items, molded pads are reusable and require less labor for application. However, since they are produced by custom lots, individual pads cost considerably more than equal quantities of sheet-stock material.

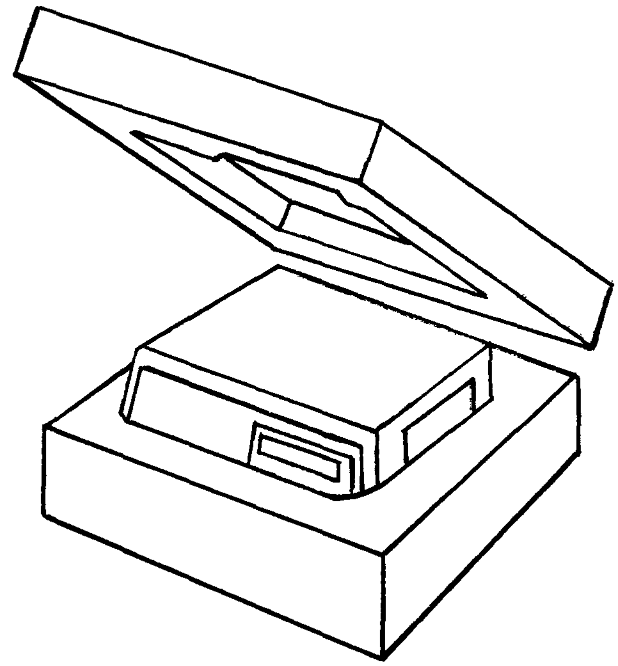


**Figure 7-29. Use of Molded Pads**

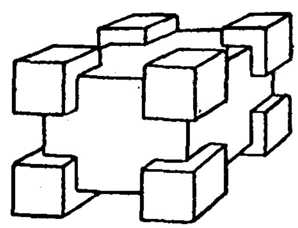


**Figure 7-30. Cushioning With Corner Pads**

### 7-5.2 CORNER PADS

Properly designed corner pads can effectively protect items having square corners and which provide more than sufficient surface area to satisfy the cushion stress requirements. The versatility of this suspension scheme and its minimum use of material enhance its economic feasibility. Fig. 7-30 illustrates cushioning with corner pads.

### 7-5.3 YOKE SUPPORTS

Yoke type cushion supports may be applied to protect irregularly shaped objects where contact with the item is limited to specific bearing points. The number of yoke assemblies used is a function of the available bearing points and the load distribution of the cushioned item. A yoke support is illustrated in Fig. 7-31.

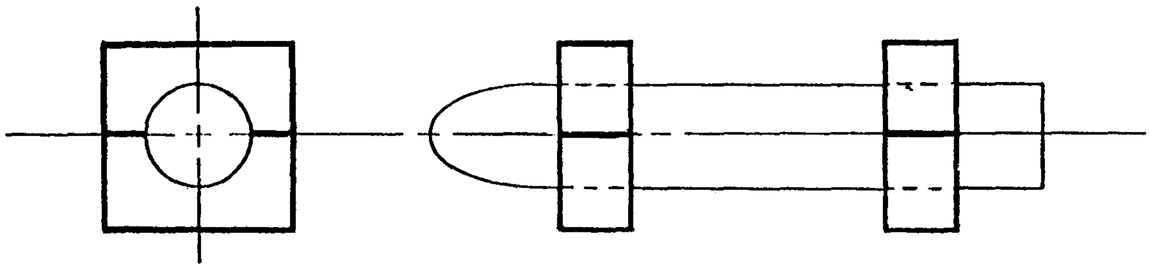


Figure 7-31. Yoke Supports

## 7-5.4 BEARING AREA

The effective bearing area of items having basic geometric configurations can be conveniently determined by simple calculations. The area of that side or end subjected to the impact of a free-fall flat drop must function to distribute this impact over as much cushion surface area as may be required to assure effective performance.

The calculation of the effective bearing area of basic geometric configurations subject to cornerwise free-fall drops is rather complex. In cornerwise-drop tests of complete packages, specifications usually require that when dropped, the corner to be impacted must be aligned along a vertical line through the center of gravity for the package (Fig. 7-32). Upon impact, the item, due to its inertia, tends to continue moving vertically downward without rotation, and the supporting cushioning (except that located in close proximity to the impacted corner) is loaded to some degree in shear.

If an item is *completely encapsulated* in material, the effective bearing area $A_T$ of the item for this situation is the projected bearing area in the horizontal plane of the three sides adjacent to the impacted corner of the item. For example, the effective bearing area of the hypothetical, homogeneous item depicted in cornerwise-impact attitude in Fig. 7-32 would be the summation of the shaded areas shown in the top view. This area can be measured by light projection methods, or it can be computed for the different conditions described in the paragraphs that follow.

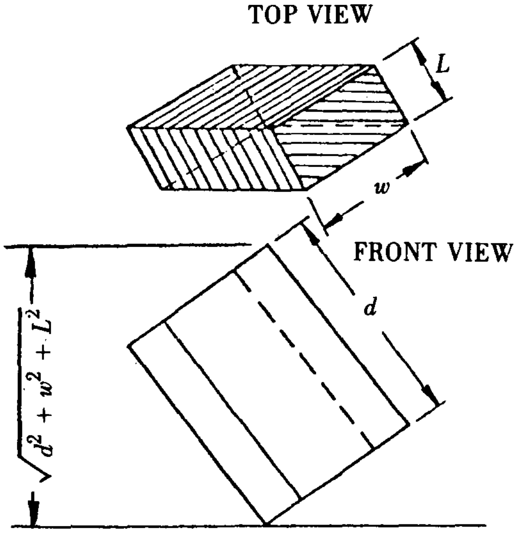



Figure 7-32. Hypothetical Homogeneous Item in Cornerwise-Impact Attitude

Obviously, $A_T$ is a function of $L$, $w$, and $d$—defined in Fig. 7-32—of the item. For any item that is a rectangular prism, the relationship between $A_T$ and $L$, $w$, and $d$ is:

$$A_T = \frac{3Lwd}{\sqrt{L^2+w^2+d^2}} \tag{7-4}$$

where $L$, $w$, and $d$ are expressed in identical units.

If the item is a cube, Eq. 7-4 reduces to:

$$A_T = 1.73\,L^2. \tag{7-5}$$

The effective bearing area of irregularly shaped items subject to flat and cornerwise impacts can be found by light projection methods. This can be accomplished by holding the item on the floor in the proper impact attitude directly below an illuminated light bulb. The effective bearing area is the area within the shadow cast by the item. The light bulb should be located a sufficient distance away so as to minimize the error caused by parallax.

The described light projection method for determining the effective bearing area of items is suitable when the cushioning material is to be applied by complete encapsulation, but it is unsuitable for application by corner or side pads.

The effective bearing area $A_T'$ of *corner pads* functioning to protect items subject to cornerwise impacts is also a function of $L$, $w$, and $d$ of the item. $A_T'$ is given as:

$$A_T' = \frac{S^2\,(d + w + L)}{\sqrt{d^2 + w^2 + L^2}} \tag{7-6}$$

where $S$ is the length of the side of one of the corner pads, as shown in Fig. 7-33.

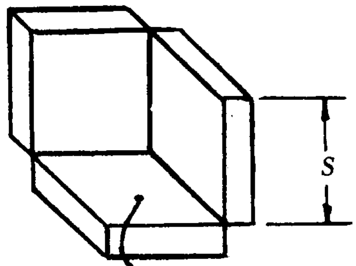



**Figure 7-33. Effective Bearing Area of Corner Pads**

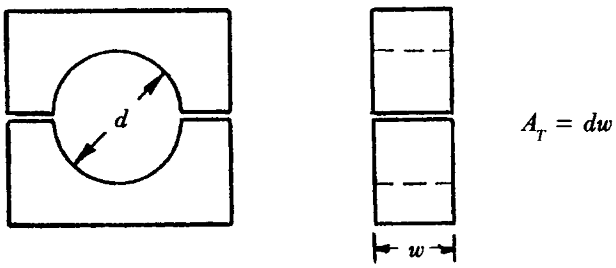



**Figure 7-34. Effective Bearing Area of Semicircular Yoke Supports**

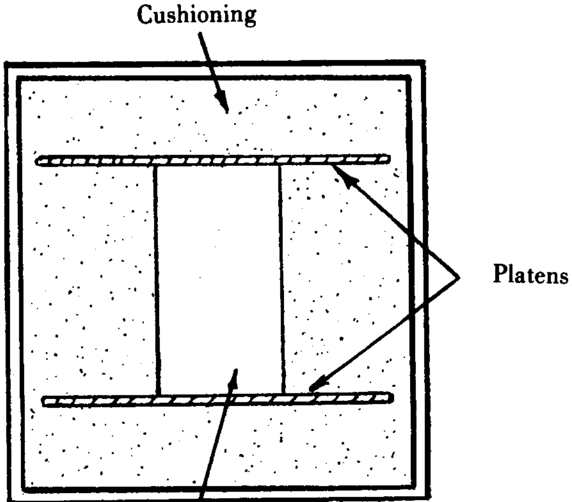



**Figure 7-35. Load-Bearing Platens Used to Increase Bearing Area of an Item Against Cushions**

Because of the complexity of the phenomena involved, it is not feasible to calculate $A_T'$ when *side cushioning pads* are used. In such instances, the most practical recourse for the designer is simply to bypass the analytical check for cornerwise drop protection. However, it is essential to check the effectiveness of the design for both flat and cornerwise drop protection by conducting actual tests of the complete package.

The effective bearing area of *semicircular yoke* support cushions is equal to the product of the diameter *d* and width *w* of the yoke as shown in Fig. 7-34.

### 7-5.5 BEARING AREA ADJUSTMENT

The use of a cushioning material in its optimum load-bearing range often requires the use of a pad size greater or less than the full bearing area of the load-producing protected item. In general, this is necessary to minimize peak impact forces by allowing light items to compress the cushioning material appreciably and preventing heavy items from bottoming during impact. Common techniques for obtaining cushioning bearing areas either larger or smaller than the adjacent sides of the items are presented.

The principal device employed to *increase* the load-bearing area of an item against a cushion is a load spreader or platen (Fig. 7-35) usually made of fiberboard or plywood. The designer should select platens that are stiff enough to distribute the load without flexing appreciably.

*Reduction* of the bearing area of an item against its cushion can be achieved by making the outside bearing area of the cushioning less than the inside bearing area of the cushioning. This is easily accomplished in foamed cushioning materials by molding ribs into the cushion (Fig. 7-36). This method of cushioning is recommended since an item subjected to shock loading remains firmly encapsulated, which tends to offset the detrimental effects of compression set and the resulting loss of restraint of the package item. Although the item and cushion as a unit may be loose within the outer container, the cushion will provide greater protection to the item than if the item were loose in the cushion. Bearing areas can also be reduced by the use of corner or side pads.

## 7-6 CUSHION DESIGN WITH SUPERIMPOSED DYNAMIC CUSHIONING CURVES

*G*-level versus static stress curves have generally been accepted as the most practical basis for indicating the shock absorption capability of cushioning

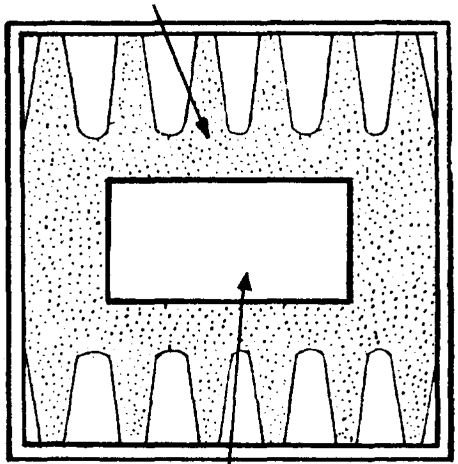



**Figure 7-36. Ribbed Cushion Used to Reduce Bearing Area of an Item Against Cushions**

materials. This type of curve is essentially a plot of the variation in item deceleration as a function of the static weight per unit area of load. A single *G*-level versus static stress curve represents the dynamic compressive response of a single cushion for a particular material thickness, density, and type, and at a specific drop height and temperature.

The shape of *G*-level versus static stress curves indicates the versatility and efficiency of the materials. The closer the curve approaches a *G*-level of zero, the better the protection afforded a fragile item. Materials characterized by curves occurring through a broad static stress range are more versatile than those that extend through a more limited range.

### 7-6.1 TEMPERATURE SENSITIVE IMPACT RESPONSE MODELS

The consideration of temperature effects by the cushioning system designer causes the material evaluation problem to become more complex. Conventional dynamic cushioning curves were developed at 70°F. Consequently, the consideration of one additional temperature will double the number of curves which are necessary to describe the situation—all other parameters held constant. It becomes obvious that a data explosion of this type soon becomes unmanageable for the container designer.

A viable alternative to this situation is to develop a general mathematical model which encompasses the pertinent parameters of the cushioning environment and can provide the desired dynamic cushioning curves from drop test data. Consideration of this alternative results in specific parameter values identified as:

| | |
|---|---|
| a. Drop height $h$: | 12 in., 18 in., 24 in., 30 in. |
| b. Thickness $T$: | 1 in., 2 in., 3 in., 4 in. |
| c. Temperature $\theta$: | -65°F, +70°F, +160°F; -20°F, +20°F, +110°F |
| d. Static Stress $W/A$: | 0.03 to 5.00 psi in various increments. |

A drop test program was designed and implemented at MICOM to acquire the required data on the following cushioning material:

a. Minicel—a cross-linked closed cell, polyethylene foam of 2 lb/ft$^3$ density
b. Ethafoam 2—linear polyethylene foam of 2 lb/ft$^3$ density
c. Ethafoam 4—linear polyethylene foam of 4 lb/ft$^3$ density
d. Urether 3—ether type polyurethane foam of 3 lb/ft$^3$ density
e. Urester 4—ester type polyurethane foam of 4 lb/ft$^3$ density.

The specific mathematical models for these five cushioning materials are given in Tables 7-1 through 7-5 (Ref. 9). Each model is based upon the unique characteristics possessed by the cushioning material. The tables are arranged so that a nonzero coefficient indicates that the variable(s) to the right, identified with an "x" is(are) part of that model. The general form of the model is:

$$G\text{-level} = c_0 + \sum_{\ell=0}^{1} h^{\ell/2} \sum_{k=0}^{1} \frac{1}{T^{(1/2+k)}} \times \sum_{j=1}^{3} \theta^j \sum_{i=0}^{2} c_{ijk\ell} \left(\ln 100 \frac{W}{A}\right) \quad (7\text{-}7)$$

It is now possible to substitute the desired values of $h$, $T$, $\theta$, and $W/A$ into the models in Tables 7-1 through 7-5; the choice depends upon which material is desired. The result will be the *G*-level value for the identified conditions.

Use of the models in this manner is not very time or cost-effective. Consequently, par. 7-6.2 discusses how the models may be optimized.

### 7-6.2 MODEL OPTIMIZATION

The optimal cushioning system provides the protected item with the necessary shock isolation at a

TABLE 7-1. MINICEL MODEL

| Variable | Coefficient | $\theta$ | $\theta^2$ | $\theta^3$ | $h^{1/2}$ | $T^{-1/2}$ | $T^{-3/2}$ | $\ln 100 \frac{W}{A}$ | $\left(\ln 100 \frac{W}{A}\right)^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | - 8.3931602 | | | | | | | | |
| 1 | 0.0 | x | | | | x | | | |
| 2 | 0.0 | x | | | | x | | x | |
| 3 | 3.5419457 | x | | | | x | | | x |
| 4 | 0.0 | x | | | x | | x | | |
| 5 | - 15.318724 | x | | | x | | x | x | |
| 6 | 3.340187 | x | | | x | | x | | x |
| 7 | 207.49326 | x | | | x | x | | | |
| 8 | - 50.359563 | x | | | x | x | | x | |
| 9 | 1.4344456 | x | | | x | x | | | x |
| 10 | 0.0 | | x | | | x | | | |
| 11 | - 6.6958791 | | x | | | x | | x | |
| 12 | 0.0 | | x | | | x | | | x |
| 13 | 0.0 | | x | | x | | x | | |
| 14 | 0.0 | | x | | x | | x | x | |
| 15 | 0.0 | | x | | x | | x | | x |
| 16 | - 54.656687 | | x | | x | x | | | |
| 17 | 11.621323 | | x | | x | x | | x | |
| 18 | 0.0 | | x | | x | x | | | x |
| 19 | - 1.3016393 | | | x | | x | | | |
| 20 | 2.0789886 | | | x | | x | | x | |
| 21 | - 0.226642 | | | x | | x | | | x |
| 22 | - 0.40141035 | | | x | x | | x | | |
| 23 | 0.61173036 | | | x | x | | x | x | |
| 24 | - 0.0953190 | | | x | x | | x | | x |
| 25 | 3.9422841 | | | x | x | x | | | |
| 26 | - 0.8660377 | | | x | x | x | | x | |
| 27 | 0.0 | | | x | x | x | | | x |
| 28 | -233.77506 | x | | | | | x | | |
| 29 | 28.303458 | x | | | | | x | x | |
| 30 | 0.0 | x | | | | | x | | x |
| 31 | 49.67875 | | x | | | | x | | |
| 32 | 26.32324 | | x | | | | x | x | |
| 33 | - 6.0678372 | | x | | | | x | | x |
| 34 | 0.0 | | | x | | | x | | |
| 35 | - 6.1520847 | | | x | | | x | x | |
| 36 | 1.0752888 | | | x | | | x | | x |

**TABLE 7-2. ETHAFOAM 2 MODEL**

| Variable | Coefficient | $\theta$ | $\theta^2$ | $\theta^3$ | $h^{1/2}$ | $T^{-1/2}$ | $T^{-3/2}$ | $\ln 100 \frac{W}{A}$ | $\left(\ln 100 \frac{W}{A}\right)^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 22.673363 | | | | | | | | |
| 1 | 0.0 | x | | | | x | | | |
| 2 | 0.0 | x | | | | x | | x | |
| 3 | 0.0 | x | | | | x | | | x |
| 4 | - 38.759499 | x | | | x | | x | | |
| 5 | 0.0 | x | | | x | | x | x | |
| 6 | 1.2835002 | x | | | x | | x | | x |
| 7 | 202.39926 | x | | | x | x | | | |
| 8 | — 53.355374 | x | | | x | x | | x | |
| 9 | 2.9700805 | x | | | x | x | | | x |
| 10 | 0.0 | | x | | | x | | | |
| 11 | 0.0 | | x | | | x | | x | |
| 12 | 0.0 | | x | | | x | | | x |
| 13 | 5.9886026 | | x | | x | | x | | |
| 14 | 0.0 | | x | | x | | x | x | |
| 15 | 0.0 | | x | | x | | x | | x |
| 16 | - 45.752170 | | x | | x | x | | | |
| 17 | 8.1253357 | | x | | x | x | | x | |
| 18 | 0.0 | | x | | x | x | | | x |
| 19 | 0.0 | | | x | | x | | | |
| 20 | 0.0 | | | x | | x | | x | |
| 21 | - 0.0096247456 | | | x | | x | | | x |
| 22 | 0.0 | | | x | x | | x | | |
| 23 | 0.0 | | | x | x | | x | x | |
| 24 | - 0.02080280 | | | x | x | | x | | x |
| 25 | 2.2706984 | | | x | x | x | | | |
| 26 | 0.0 | | | x | x | x | | x | |
| 27 | - 0.067325251 | | | x | x | x | | | x |
| 28 | -418.94060 | x | | | | | x | | |
| 29 | 156.40775 | x | | | | | x | x | |
| 30 | - 15.003939 | x | | | | | x | | x |
| 31 | 133.99966 | | x | | | | x | | |
| 32 | - 38.926690 | | x | | | | x | x | |
| 33 | 2.2685893 | | x | | | | x | | x |
| 34 | - 10.473401 | | | x | | | x | | |
| 35 | 2.1412173 | | | x | | | x | x | |
| 36 | 0.0 | | | x | | | x | | x |

TABLE 7-3. ETHAFOAM 4 MODEL

| Variable | Coefficient | $\theta$ | $\theta^2$ | $\theta^3$ | $h^{1/2}$ | $T^{-1/2}$ | $T^{-3/2}$ | $\ln 100 \frac{W}{A}$ | $\left(\ln 100 \frac{W}{A}\right)^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 32.918823 | | | | | | | | |
| 1 | - 48.167497 | x | | | | x | | | |
| 2 | 0.0 | x | | | | x | | x | |
| 3 | 0.0 | x | | | | x | | | x |
| 4 | 0.0 | x | | | x | | x | | |
| 5 | - 41.636209 | x | | | x | | x | x | |
| 6 | 6.0138922 | x | | | x | | x | | x |
| 7 | 216.47081 | x | | | x | x | | | |
| 8 | - 33.446350 | x | | | x | x | | x | |
| 9 | 0.0 | x | | | x | x | | | x |
| 10 | 0.0 | | x | | | x | | | |
| 11 | 4.3398390 | | x | | | x | | x | |
| 12 | 0.0 | | x | | | x | | | x |
| 13 | 0.0 | | x | | x | | x | | |
| 14 | 9.4729454 | | x | | x | | x | x | |
| 15 | - 1.0063034 | | x | | x | | x | | x |
| 16 | - 51.701093 | | x | | x | x | | | |
| 17 | 3.6887819 | | x | | x | x | | x | |
| 18 | 0.55314362 | | x | | x | x | | | x |
| 19 | 0.0 | | | x | | x | | | |
| 20 | 0.0 | | | x | | x | | x | |
| 21 | - 0.10103962 | | | x | | x | | | x |
| 22 | - 0.21961366 | | | x | x | | x | | |
| 23 | - 0.33423026 | | | x | x | | x | x | |
| 24 | 0.0 | | | x | x | | x | | x |
| 25 | 3.2311604 | | | x | x | x | | | |
| 26 | 0.0 | | | x | x | x | | x | |
| 27 | - 0.054746082 | | | x | x | x | | | x |
| 28 | -253.15131 | x | | | | | x | | |
| 29 | 136.46772 | x | | | | | x | x | |
| 30 | - 11.86598 | x | | | | | x | | x |
| 31 | 72.15674 | | x | | | | x | | |
| 32 | - 25.154675 | | x | | | | x | x | |
| 33 | 0.0 | | x | | | | x | | x |
| 34 | - 4.1437095 | | | x | | | x | | |
| 35 | 0.0 | | | x | | | x | x | |
| 36 | 0.357168 | | | x | | | x | | x |

**TABLE 7-4. URETHER 3 MODEL**

| Variable | Coefficient | $\theta$ | $\theta^2$ | $\theta^3$ | $h^{1/2}$ | $T^{-1/2}$ | $T^{-3/2}$ | $\ln 100 \frac{W}{A}$ | $\left(\ln 100 \frac{W}{A}\right)^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 16.456637 | | | | | | | | |
| 1 | 0.0 | x | | | | x | | | |
| 2 | 0.0 | x | | | | x | | x | |
| 3 | 13.28693 | x | | | | x | | | x |
| 4 | − 8.6616181 | x | | | x | | x | | |
| 5 | 0.0 | x | | | x | | x | x | |
| 6 | 0.0 | x | | | x | | x | | x |
| 7 | 63.974659 | x | | | x | x | | | |
| 8 | − 9.0835167 | x | | | x | x | | x | |
| 9 | − 4.6111397 | x | | | x | x | | | x |
| 10 | 0.0 | | x | | | x | | | |
| 11 | 3.474952 | | x | | | x | | x | |
| 12 | − 5.9426191 | | x | | | x | | | x |
| 13 | 0.40180109 | | x | | x | | x | | |
| 14 | 1.8227191 | | x | | x | | x | x | |
| 15 | 0.0 | | x | | x | | x | | x |
| 16 | − 18.556063 | | x | | x | x | | | |
| 17 | 0.0 | | x | | x | x | | x | |
| 18 | 2.2398188 | | x | | x | x | | | x |
| 19 | − 0.71661025 | | | x | | x | | | |
| 20 | 0.0 | | | x | | x | | x | |
| 21 | 0.49953221 | | | x | | x | | | x |
| 22 | 0.0 | | | x | x | | x | | |
| 23 | − 0.15167925 | | | x | x | | x | x | |
| 24 | − 0.015276062 | | | x | x | | x | | x |
| 25 | 1.6300623 | | | x | x | x | | | |
| 26 | 0.0 | | | x | x | x | | x | |
| 27 | − 0.19795351 | | | x | x | x | | | x |
| 28 | 21.394161 | x | | | | | x | | |
| 29 | − 18.657059 | x | | | | | x | x | |
| 30 | 0.0 | x | | | | | x | | x |
| 31 | 0.0 | | x | | | | x | | |
| 32 | 0.0 | | x | | | | x | x | |
| 33 | 0.40841278 | | x | | | | x | | x |
| 34 | 0.0 | | | x | | | x | | |
| 35 | 0.0 | | | x | | | x | x | |
| 36 | 0.0 | | | x | | | x | | x |

TABLE 7-5. URESTER 4 MODEL

| Variable | Coefficient | $\theta$ | $\theta^2$ | $\theta^3$ | $h^{1/2}$ | $T^{-1/2}$ | $T^{-3/2}$ | $\ln 100 \frac{W}{A}$ | $\left(\ln 100 \frac{W}{A}\right)^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 559.746 | | | | | | | | |
| 1 | 0.0 | x | | | | x | | | |
| 2 | 0.0 | x | | | | x | | x | |
| 3 | 0.0 | x | | | | x | | | x |
| 4 | -107.90113 | x | | | x | | x | | |
| 5 | 32.951647 | x | | | x | | x | x | |
| 6 | -3.7757261 | x | | | x | | x | | x |
| 7 | 206.02943 | x | | | x | x | | | |
| 8 | -49.889708 | x | | | x | x | | x | |
| 9 | -5.0392425 | x | | | x | x | | | x |
| 10 | 0.0 | | x | | | x | | | |
| 11 | 0.0 | | x | | | x | | x | |
| 12 | 0.0 | | x | | | x | | | x |
| 13 | 19.77191 | | x | | x | | x | | |
| 14 | 0.0 | | x | | x | | x | x | |
| 15 | 0.0 | | x | | x | | x | | x |
| 16 | -56.422968 | | x | | x | x | | | |
| 17 | 7.8434679 | | x | | x | x | | x | |
| 18 | 3.1828843 | | x | | x | x | | | x |
| 19 | 0.0 | | | x | | x | | | |
| 20 | 0.0 | | | x | | x | | x | |
| 21 | 0.0 | | | x | | x | | | x |
| 22 | 0.0 | | | x | x | | x | | |
| 23 | -1.0933512 | | | x | x | | x | x | |
| 24 | 0.14231548 | | | x | x | | x | | x |
| 25 | 3.7496497 | | | x | x | x | | | |
| 26 | 0.0 | | | x | x | x | | x | |
| 27 | -0.36983233 | | | x | x | x | | | x |
| 28 | 0.0 | x | | | | | x | | |
| 29 | 0.0 | x | | | | | x | x | |
| 30 | 10.179855 | x | | | | | x | | x |
| 31 | 48.384712 | | x | | | | x | | |
| 32 | -31.619216 | | x | | | | x | x | |
| 33 | 0.0 | | x | | | | x | | x |
| 34 | -9.0192091 | | | x | | | x | | |
| 35 | 5.953565 | | | x | | | x | x | |
| 36 | -0.43214979 | | | x | | | x | | x |
| 37 | -213.634 | x | | | | | | | |
| 38 | 0.0 | x | | | | | | x | |
| 39 | 8.2119242 | x | | | | | | | x |
| 40 | 0.0 | | x | | | | | | |
| 41 | 14.258078 | | x | | | | | x | |
| 42 | -5.0076278 | | x | | | | | | x |
| 43 | 3.5699545 | | | x | | | | | |
| 44 | -2.4343742 | | | x | | | | x | |
| 45 | 0.59891583 | | | x | | | | | x |

minimum cost. Obviously, one of the cushioning system costs is the amount of cushioning material required to provide the desired protection. Therefore, a minimum, though optimum cushion thickness, will minimize cushion cost and the entire cost of item protection, transportation, and storage.

Since it is desirable to use the developed models in a computerized fashion, a procedure is necessary which permits an iterative approach to the determination of the minimum cushion thickness. For optimization purposes, the fragility level of the protected item is identified as $(GL)_{max}$. The temperature parameter $\theta$ relates the expected temperature extremes as $\theta_{min}$ and $\theta_{max}$. The previously introduced superimposed dynamic cushioning curve approach is used for this purpose.

Ordinarily, the fragility level of the protected item is specified as part of the hardware specifications in the military system design criteria. The applicable temperature range ($\theta_{min}$, $\theta_{max}$) is defined in the missile system requirements. The expected drop height $h$ is specified in various Military Standards and depends upon the total container weight and size. The parameters $(GL)_{max}$, $\theta_{min}$, $\theta_{max}$, and $h$ are the external variables in the optimization model. The internal variables are the static stress level $W/A$ and the cushion thickness $T$. Since the cushion thickness is the variable which is to be minimized, the variable $T_{min}$ may be described as:

$$T_{min} = f[\, W/A, (GL)_{max}, \theta_{min}, \theta_{max}, h]. \quad (7\text{-}8)$$

The procedure searches this functional relationship for the minimum thickness of cushion that will perform satisfactorily at the determined static stress condition. The search is subject to certain constraints such as $\theta_{min} < \theta < \theta_{max}$ and $G$-level $\leq (GL)_{max}$. It is important to recognize that when the external variables are introduced into the $T_{min}$ Eq. 7-8, a two-dimensional search on $W/A$ and $T$ is all that is required (Ref. 10).

## 7-6.3 DIRECT SEARCH ROUTINE

The identification of the item fragility level $(GL)_{max}$ permits the search for the minimum cushion thickness to be initiated. As a means of permitting design flexibility and also reducing creep problems within the design, the acceptable static stress range at $(GL)_{max}$ has been input to be greater than 0.2 psi. Basically, the direct search routine is composed of several distinct steps. The initial step provides the designer with the opportunity to select the cushioning material type to be used. It is anticipated that a data base will eventually be available that contains valid impact response models for many of the different types of bulk cushioning materials in addition to the five previously presented.

Next, the search is initiated on the minimum feasible cushion thickness, i.e., 1 in. Few, if any, cushion designers will use less than 1 in. of cushioning material in a cushioning application based upon the economics of acquiring the smaller thicknesses. The other parameters $\theta_{min}$, $\theta_{max}$, and $h$ have been input into the model by the designer and specify which superimposed dynamic cushioning curves will be investigated initially. The search is first conducted across the specified static stress spectrum, usually 0.03 to 5.00 psi, on the low temperature curve $\theta_{min}$, to determine the feasibility of meeting the stipulated $(GL)_{max}$. If the search on the 1-in. thickness, low temperature curve is unsuccessful—i.e., the curve does not possess $G$-level values below $(GL)_{max}$—the thickness is incremented 0.5 in. and the search begins anew. The search on the low temperature curve continues until a feasible curve is identified where $G$-level $< (GL)_{max}$ or the search exceeds the current cushion thickness data base limitation of 4 in.

The search now turns to the high temperature curve at the same thickness as the feasible low temperature curve which was previously identified. If the search on this curve is unsuccessful, the thickness is incremented 0.5 in. and the search continues similarly to the low temperature curve search. Obviously, both the low and high temperature curves must be at identical cushion thicknesses for a valid solution to exist. Consequently, if the two curves are at different cushion thicknesses, the thickness of the high temperature curve prevails; the corresponding low temperature curve will also be feasible since the low temperature curve previously identified was feasible. From this feasible set of superimposed dynamic cushioning curves, the designer may now select a static stress value for cushion design. Ordinarily, the lower the static stress value, the better, since any material creep tendencies will then be minimized (Ref. 10).

## 7-6.4 THE CUSHOP PROGRAM

The developed container cushioning models may be applied, using a desk top programmable calculator such as the HP-9815A. The five developed models are contained on a cassette tape for ease of use (Ref. 9).

Any drop height between 12 and 30 in. may be employed on all five models. The Minicel, Ethafoam 2, and Ethafoam 4 models span the entire worldwide distribution temperature range, namely, -65°F to +160°F. Consequently, these three models are capa-

ble of determining cushion requirements for these three materials over the stated temperature range. The Urether 3 and Urester 4 models have been developed within a narrower temperature spectrum. Drop-test experience indicated that both materials behaved erratically below -20°F, suggesting that the materials were inconsistent at the extreme low temperatures. Therefore, the developed Urether 3 and Urester 4 models are constrained to temperature values of -20°F to +160°F.

The Cushop Program brings together—in the form of a computer code on a cassette—the five developed temperature sensitive impact response models, the model optimization procedure, and the direct search routine. This is a tailored approach to cushion design and requires that the designer specify the fragility level, drop height, cold temperature, hot temperature, item weight, and material type. Cushop then searches for the minimum material thickness which satisfies the stipulated conditions. The minimum material thickness, the static stress range, the minimum and maximum item bearing areas, and all the input parameters are output on the hard copy together with the plotted superimposed dynamic cushioning curves.

A typical output of the Cushop model is shown in Fig. 7-37. This output is associated with the Minicel cushioning material. The selected drop height is 30 in. with a fragility level of 40 *G*'s, a temperature range of -65°F to +160°F, and an item weight of 85 lb. All of this information is input by the designer and is output under the heading on each copy.

It should be noted that a horizontal line is drawn at 40 *G*'s to identify the specified fragility level. The procedure then searches through the cushion material thickness, starting at 1 in., until a cushion material thickness is identified which provides a 0.2 psi static stress range at or below the 40 *G* fragility level. The variation, which occurs as a function of temperature, within the cushion material is shown by the three parabolic-shaped curves in Fig. 7-37. The left uppermost curve C represents the cold temperature effect; the middle curve A represents the 70°F effect, while the left lowermost curve H represents the hot temperature effect. The static stress range—indicated on the fragility level line by the intersection of, first, the cold curve; and, second, by the hot curve—is identified in the heading as static stress lower ($SSL$) = 0.70 and static stress upper ($SSU$) = 1.25. Since static stress ($SS$) = $W/A$, it is possible to acquire the desired minimum and maximum bearing areas by rearranging this equation into $A = W/(SS)$. For the lower static stress,

$$A = \mathrm{W}/(SSL) = 85/0.70 = 121.43 \text{ in}^2$$

For the upper static stress,

$$A = W/(SSU) = 85/1.25 = 68.00 \text{ in}^2$$

It is noted that the lower static stress is associated with the maximum bearing area, while the upper static stress is associated with the minimum bearing area. These bearing areas represent the amount of cushion which is to be in contact with the surface of the item to be protected. Any static stress value between the upper and lower static stress limits may be selected as a feasible solution, if desired, and the corresponding surface area calculated. The result represents the safe design limits for 3 in. of Minicel cushion under the specified conditions. TOPT represents the thickness of cushion required in inches.

In this example, any cushion thickness above 3 in. will result in excessive cushioning ability with attendant increased material and transportation costs, and space requirements. Consequently, it is in the designer's best interest to use only the required amount of cushion in any design.

### 7-6.5 THE ENCAP PROGRAM

In some design considerations, the cushioning system designer is given the fragility level, drop height, item weight, minimum and maximum surface areas, and hot and cold temperatures. The desired cushioning configuration is encapsulation, which means the entire item is surrounded by the same thickness of cushion. This approach to cushion design tends to be less cost-effective than the tailored approach.

The Encap Program is designed to handle the encapsulation approach (Ref. 9). A typical output of the Encap model is shown in Fig. 7-38. This output is associated with the Ethafoam 2 cushioning material. The selected drop height is 30 in., with a fragility level of 51 *G*'s, a temperature range of -65°F to +160°F, and an item weight of 56 lb. The item to be protected has a maximum bearing surface of 9 in. by 9 in., and a minimum bearing surface of 8 in. by 8 in. It should be evident that the larger the difference in the maximum and minimum bearing areas, the wider the desired stress range becomes, and the greater the cushion thickness required.

In Fig. 7-38, the two vertical marks identified on the fragility level line represent the extremes of the calculated static stress range. The cold curve must be to the left of the leftmost mark; the hot curve must be to the right of the rightmost mark; and both curves must intersect the fragility level at the same cushion

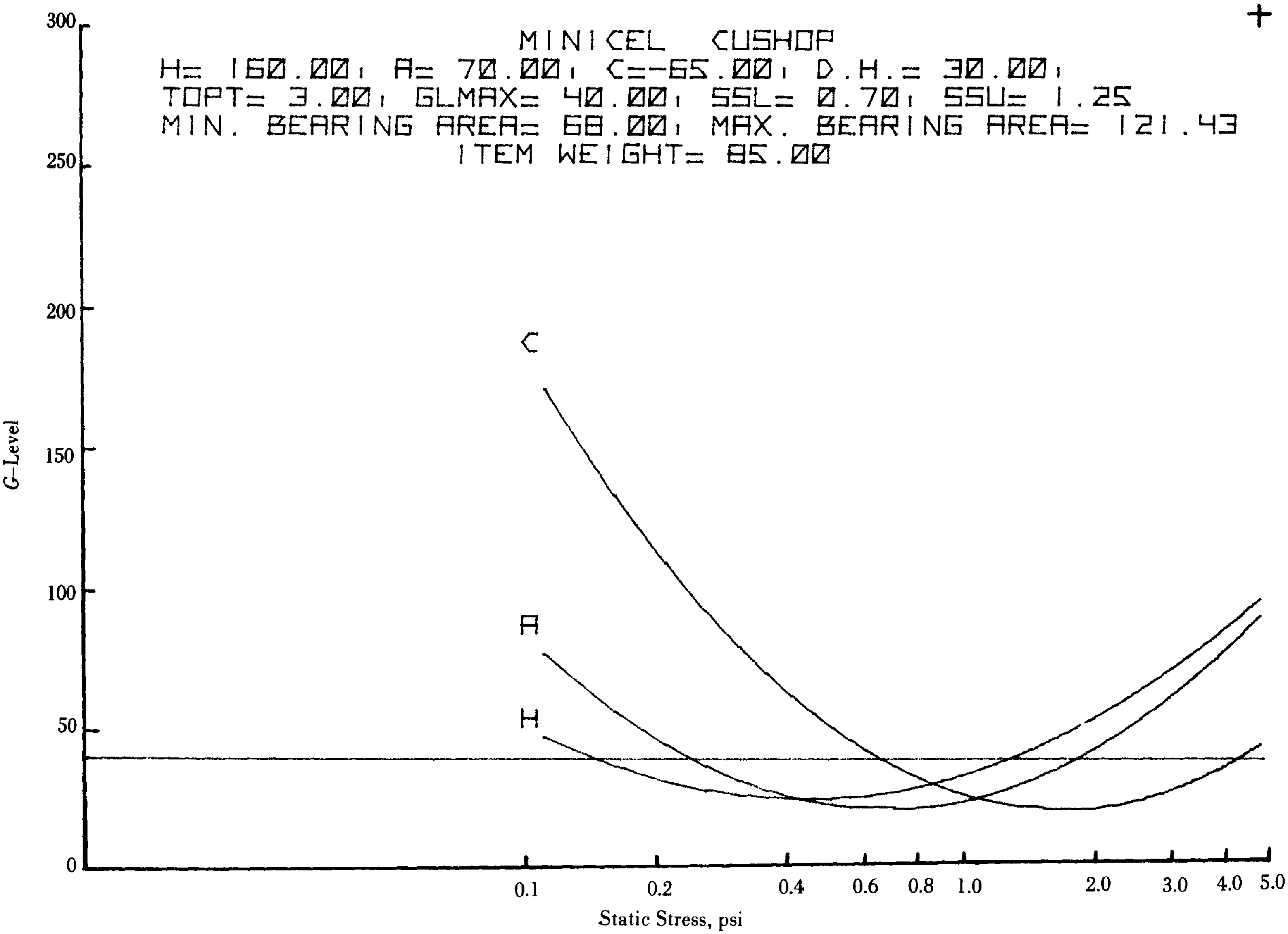



**Figure 7-37. Typical Cushop Model Output**

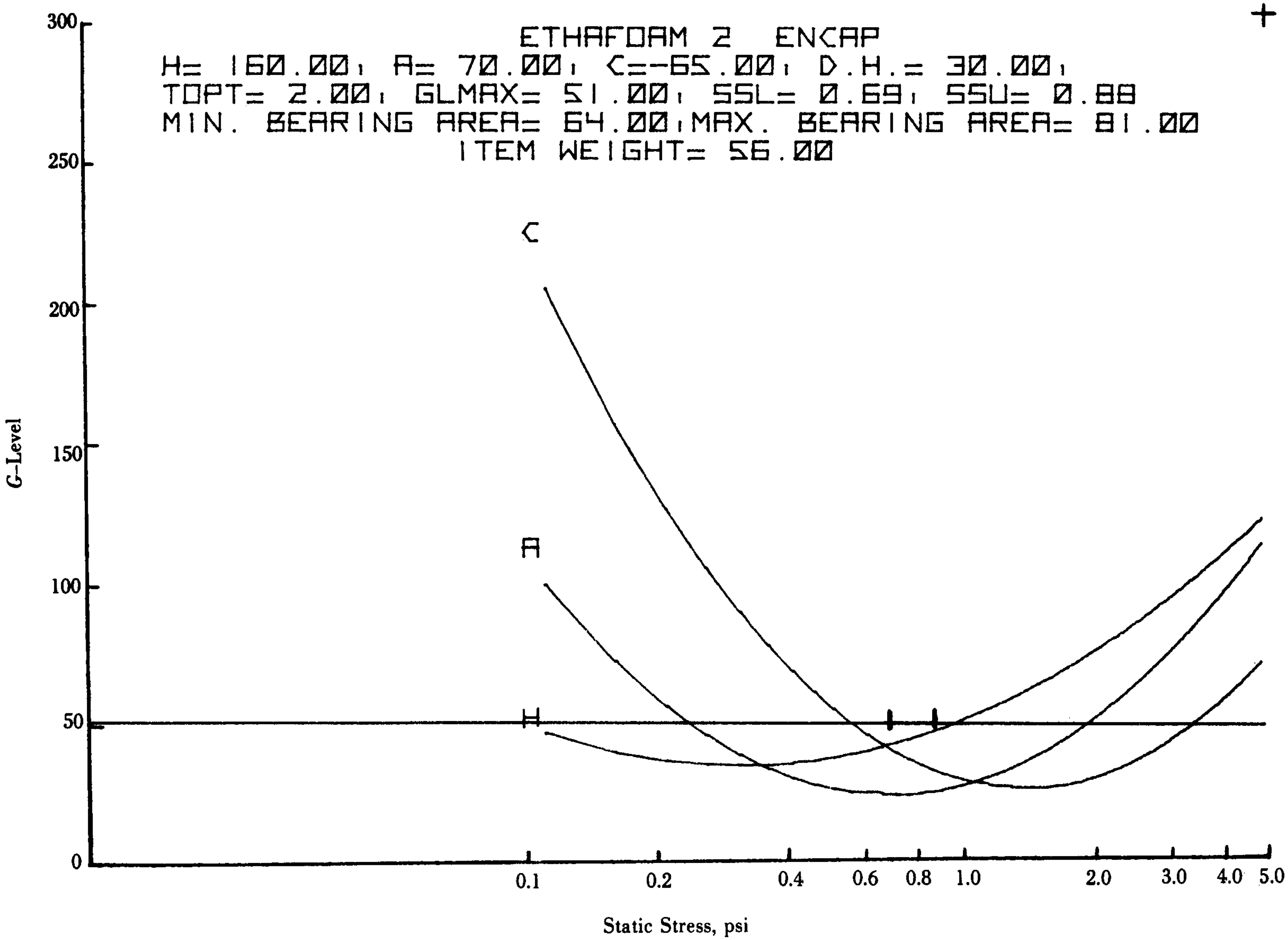



Figure 7-38. Typical Encap Model Output

thickness. TOPT equal to 2 in. represents the amount of cushion required for the specified conditions. The *SSL* level is given as 0.69, while the *SSU* level is 0.88 psi.

It is important to note that the Cushop program calculates a static stress range independent of the available surface bearing area, while Encap requires surface bearing areas as an input. Hence the tailored approach of Cushop becomes evident.

### 7-6.6 IMPLEMENTATION

The implementation of the developed models is depicted best through typical cushioning problems which are not accurately solvable with prior methods. Many real world cushioning situations exist at drop heights other than 12, 18, 24, or 30 in. Similarly, worldwide distribution requires temperature variations between -65°F and +160°F, not just at 70°F.

The sample problems that follow demonstrate how the Cushop and Encap programs provide the designer with candidate material cushion designs for a particular cushioning situation (Ref. 9). The appropriate material cushion thickness and loading intensity are specified for a desired protection level. The designer uses the Cushop and Encap analyses in his preliminary design, along with his judgment of the other factors that are expected to influence the design. These other factors include the exterior container structure and its anticipated shock attenuation characteristics, creep expectations, and also the number and type of anticipated drops.

*Example 1:*

From a cushion design standpoint, the simplest item to protect with cushioning is cube shaped. This means that all surfaces are equal in bearing area and will require the same protection on each surface. Assume the item is a 12-in. cube, weighs 97 lb, and a tailored cushion is permissible. The $(GL)_{max}$ is 30 *G*'s, the expected drop height is 26 in., and the temperature range is -60°F to +155°F.

Only the Minicel, Ethafoam 2, and Ethafoam 4 materials are capable of providing the desired protection over the specified temperature range. The results of the Cushop program for these materials at the specified conditions are given in Figs. 7-39 through 7-41.

The minimum cushion thickness required to provide the desired protection using the Minicel, Ethafoam 2, or Ethafoam 4 material is 3.5, 3.0, or 4.0 in., respectively. The cushion designer is usually interested in the low static stresses. A considerable range of lower stress levels is observed—0.75 for Minicel, 0.80 for Ethafoam 2, and 2.15 for Ethafoam 4. Consequently, the cushion designer would select the Ethafoam 2 material for his initial design, based on cushion thickness and static stress level.

Since this is a tailored cushioning approach, a side cushion must now be provided which satisfies the minimum bearing area and the upper static stress level, the maximum bearing area at the lower static stress level, or combinations between these two extremes. For this example, the entire surface area of the protected item will *not* be used.

*Example 2:*

Use the Encap program to solve the situation described in Example 1. Recall, the Encap program requires two additional input values—the maximum and minimum bearing areas in square inches. For this example, the minimum bearing area equals the maximum bearing area since the item to be protected is a cube. The bearing area value is 144 $in^2$.

The Encap program results for the specified conditions are given in Figs. 7-42 through 7-44. It is seen that the Minicel material provides the most feasible solution, using 4 in. of cushion material. The Ethafoam 2 material requires 8 in. of cushion material, while the Ethafoam 4 material is not feasible at 12 in. of cushion material. This example illustrates the problem which exists with the encapsulation approach.

*Example 3:*

This example assumes the cushion designer has the various thicknesses of the Ethafoam 2 material in stock. The item to be protected is 7 in. by 12 in. by 10 in. The $(GL)_{max}$ is 35 *G*'s, the expected drop height is 28 in., the item weighs 82 lb, and the temperature range is -50°F to +130°F. A tailored cushion is desired.

The Cushop program results for this situation are given in Fig. 7-45. The minimum cushion thickness required to provide the desired item protection is 2.5 in. of Ethafoam 2. The minimum bearing area is calculated to be 58.57 $in^2$ with a corresponding upper static stress level of 1.4 psi. The maximum bearing area is 117.14 $in^2$, and the corresponding *SSL* level is 0.70 psi. The static stress levels are not the same on each surface of this item. The actual minimum bearing area is 70 $in^2$, while the actual maximum bearing area is 120 $in^2$, with the other two surfaces at 84 $in^2$. Hence if a common stress level is to be applied to all surfaces, it must be 82/70 = 1.17 psi to 82/58.57 = 1.40 psi. A common size cushion is then placed on each surface; the size is between 58.57 and 70 $in^2$ to preclude the use of platens.

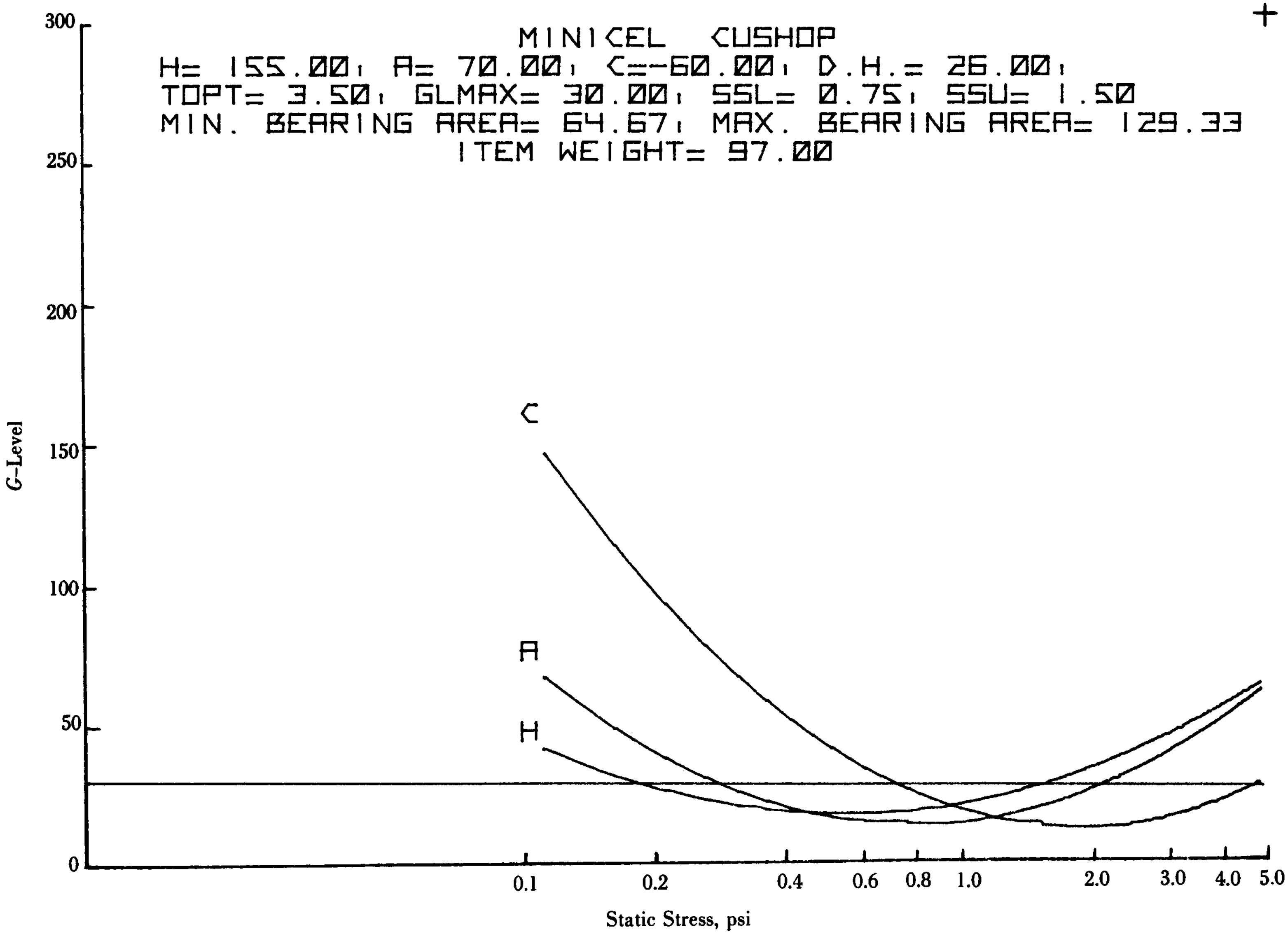



**Figure 7-39. Minicel Cushop Results for Example 1**

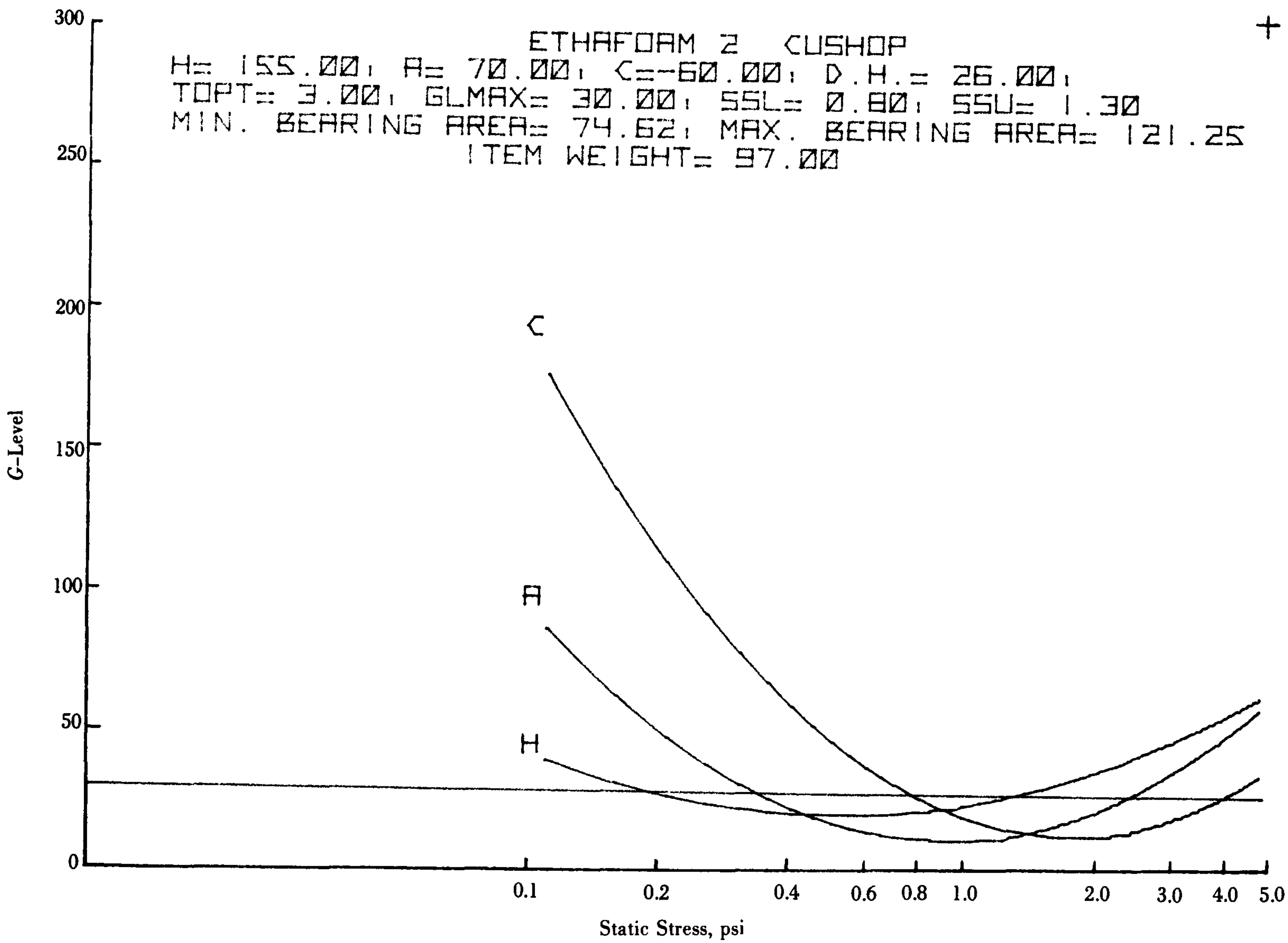



**Figure 7-40. Ethafoam 2 Cushop Results for Example 1**

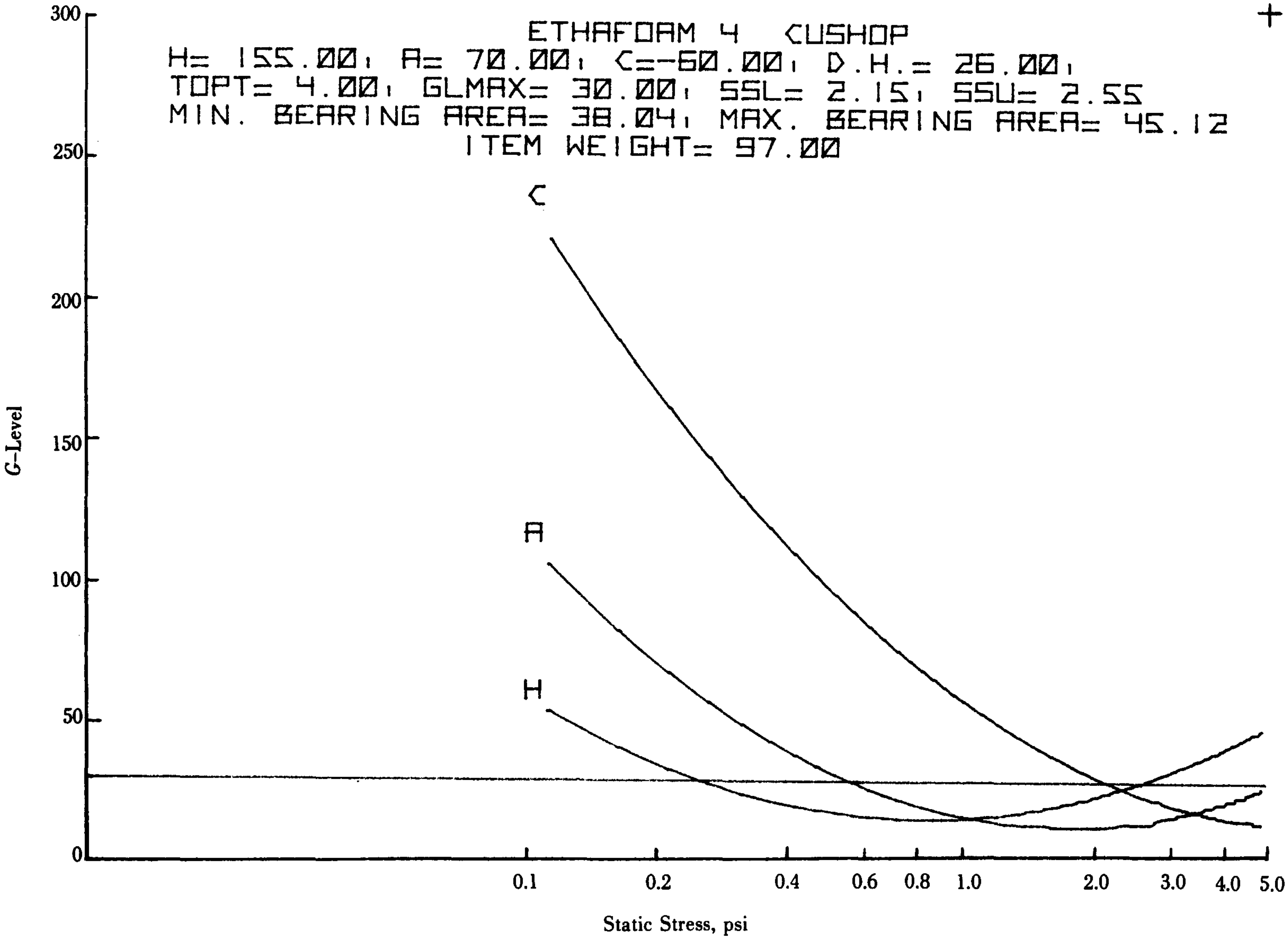



**Figure 7-41. Ethafoam 4 Cushop Results for Example 1**

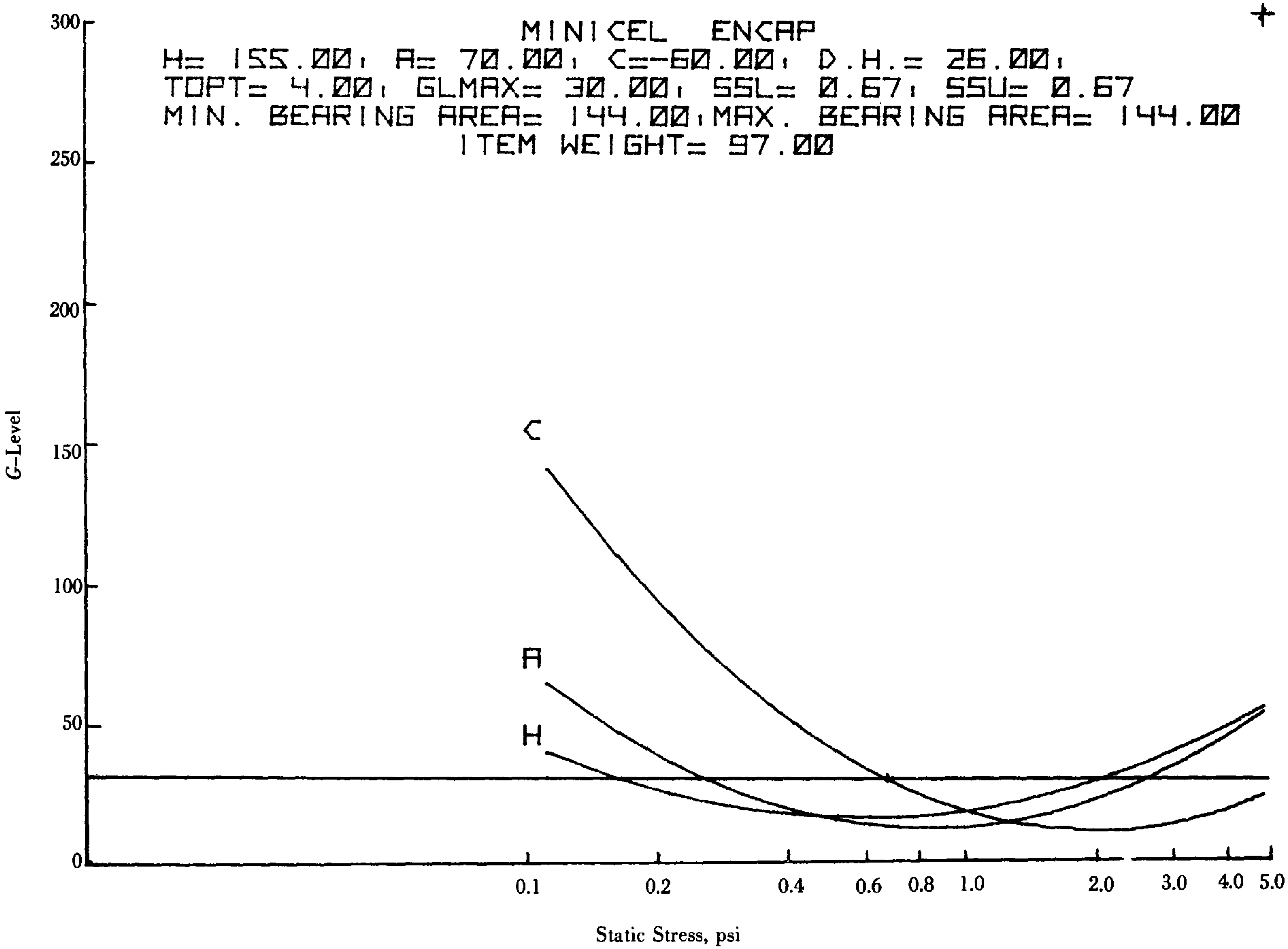



**Figure 7-42. Minicel Encap Results for Example 2**

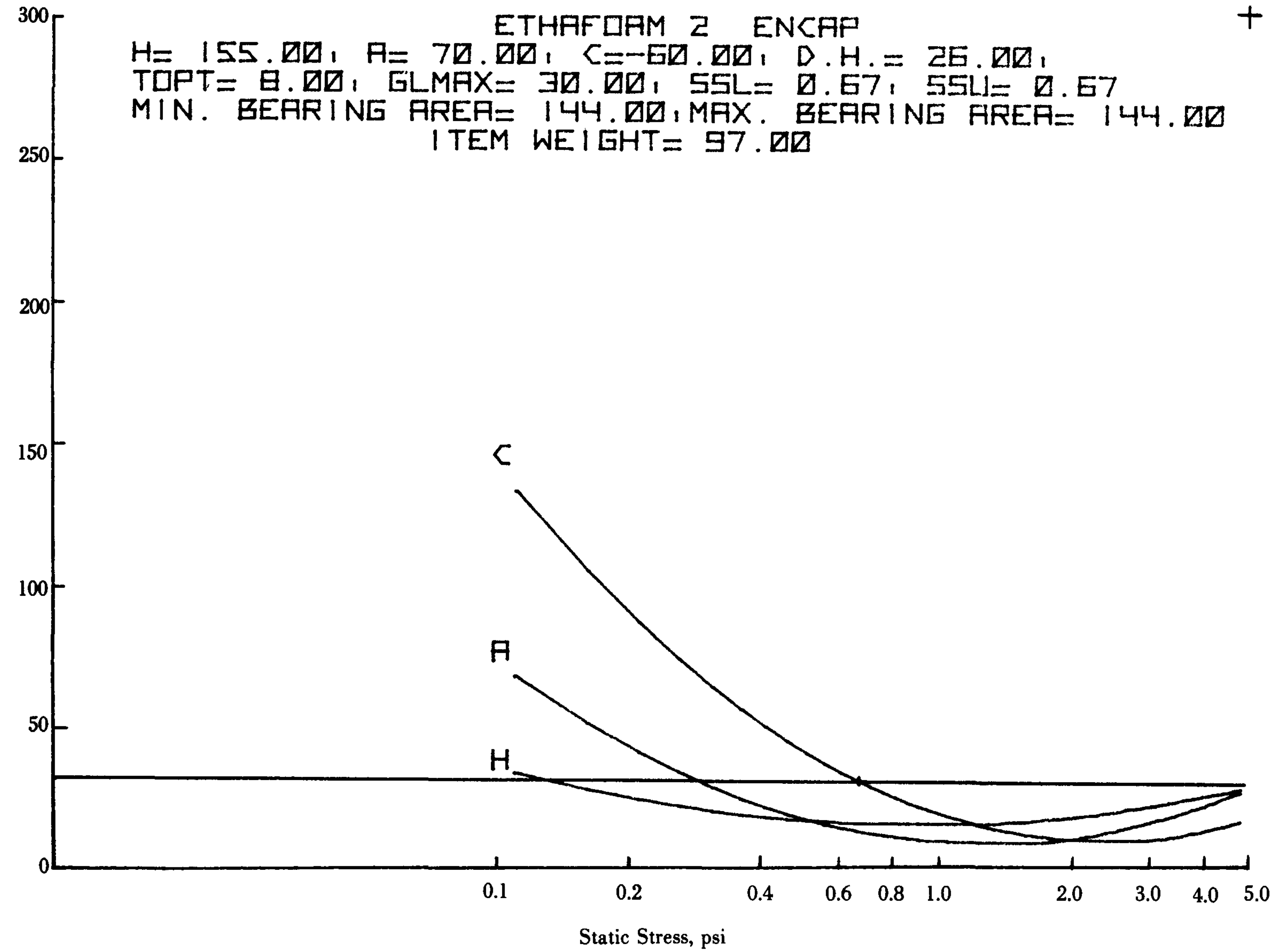



**Figure 7-43. Ethafoam 2 Encap Results for Example 2**

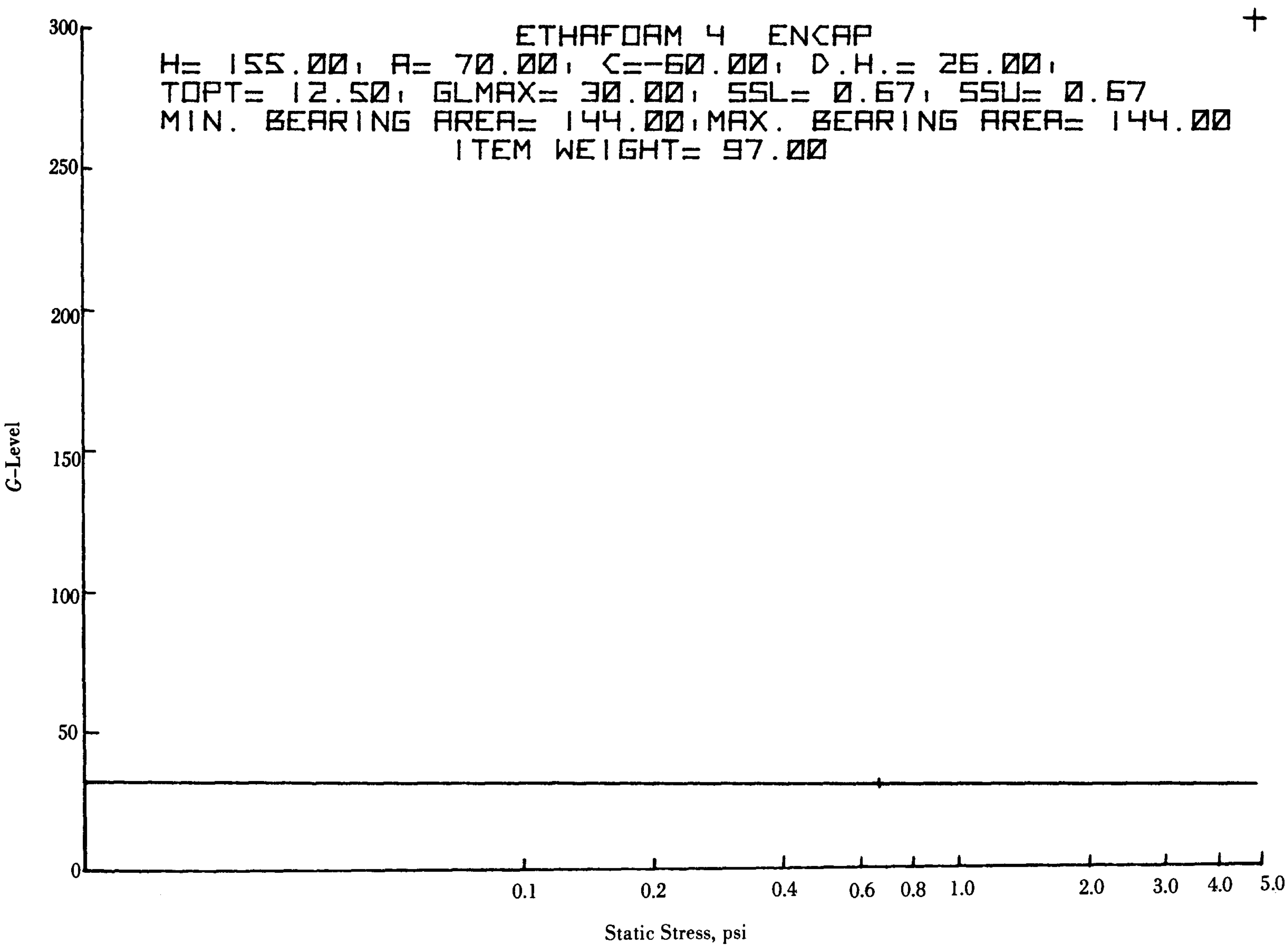



**Figure 7-44. Ethafoam 4 Encap Results for Example 2**

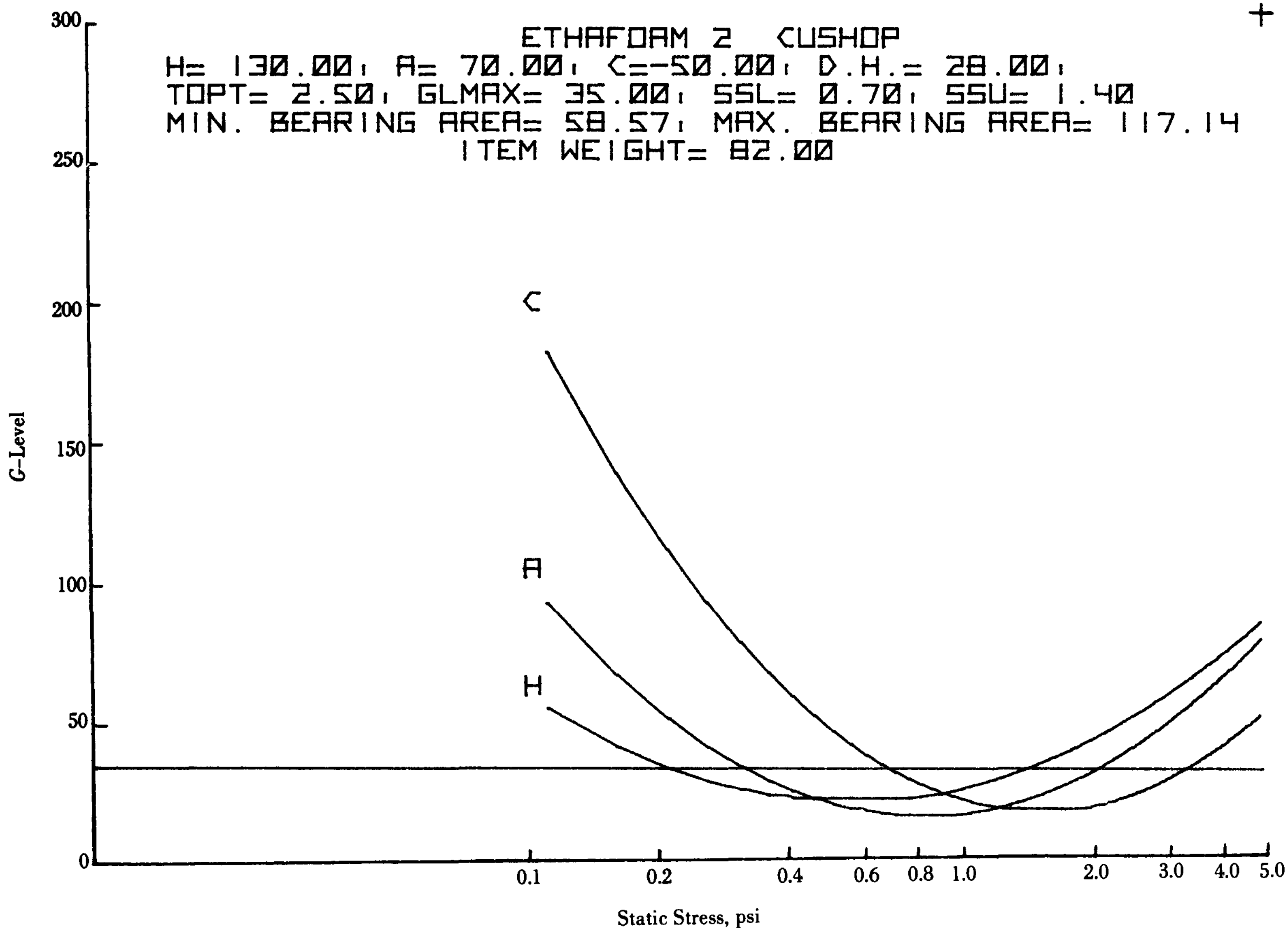



**Figure 7-45. Ethafoam 2 Cushop Results for Example 3**

*Example 4:*

The encapsulation method of cushioning is now desired for the condition described in Example 3. The minimum bearing area is 70 $in^2$ and the maximum bearing area is 120 $in^2$.

The Encap program results are given in Fig. 7-46. A cushion thickness of 3 in. is sufficient to protect the item on all surfaces to a $(GL)_{max}$ of 35 *G*'s. If the cushion designer is satisfied with the 0.60 to 1.17 psi static stress range for his design, he may use this solution directly.

*Example 5:*

Frequently, the cushion designer is very flexible with regard to cushion material selection. When the total volume of the packaged item is of primary importance, the minimum cushion thickness capable of providing the desired item protection must be identified. Consequently, all material models must be investigated for this minimum thickness.

The item to be protected is 20 in. long, 14 in. wide, and 16 in. in height. $(GL)_{max}$ is 45 *G*'s, the temperature range is -20°F to +140°F, the expected drop height is 26 in., and the item weighs 114 lb. A tailored cushion is desired.

The Cushop program results are given in Figs. 7-47 through 7-51. All five materials are capable of providing the desired protection. However, the minimum cushion thickness, 1.5 in., is possible with the Ethafoam 4 material. If a lower static stress level is desired, the Ethafoam 2 and Urether 3 materials are the next material candidates since each of them can provide the desired protection with a 2-in. cushion. A much wider stress range is then available to the cushion designer. However, should the minimum stress level for Urether 3 be selected, a rather large bearing area of 1140.0 $in^2$ becomes necessary. This may cause some unrealistic bearing area problems that are not easily resolved.

*Example 6:*

An item which is 14 in. by 14 in. on the ends and 23 in. long is to be completely protected by the Urester 4 cushioning material. The item weighs 140 lb, has a $(GL)_{max}$ of 47 *G*'s, an expected drop height of 23 in., and a temperature range of -15°F to +140°F.

Fig. 7-52 presents the Encap results for this situation. The required cushion thickness is 3 in. of Urester 4 material to provide the desired protection within a static range of 0.43 to 0.71 psi.

### 7-6.7 PROGRAM AVAILABILITY

The MICOM Cushop and Encap cushion design programs are available on cassette tape for use on a Hewlett Packard HP-9815A desk-top calculator with plotting capability provided by an HP-9862A plotter. A program listing and/or a cassette tape including the five developed models may be obtained by writing:

Commander
US Army Missile Command
ATTN: DRDMI-TLD
Redstone Arsenal, AL 35809.

In addition, a Fortran version without a plotting capability is available at the same address.

## REFERENCES

1. MIL-HDBK-304, *Package Cushioning Design*.

2. J. B. Titus, *Effect of Low Temperature (0° to -65°F) on the Properties of Plastics*, PLASTEC Report 30, Plastics Technical Evaluation Center, Picatinny Arsenal, Dover, NJ, 1967.

3. G. S. Mustin, *Theory and Practice of Cushion Design*, Shock and Vibration Information Center, Washington, DC, pp. 251-262, 1968.

4. R. M. Wyskida and M. R. Wilhelm, *Temperature Sensitive Dynamic Cushioning Function Development and Validation for Hercules Minicel Thermoplastic Foam*, UAH Research Report No. 159, **I**, The University of Alabama in Huntsville, Huntsville, AL, 1974.

5. R. M. Wyskida et al., *Temperature Sensitive Dynamic Cushioning Function Development and Validation for DOW Ethafoam Polyethylene Foam*, UAH Research Report No. 172, **I**, The University of Alabama in Huntsville, Huntsville, AL, 1975.

6. R. M. Wyskida et al., *Temperature Sensitive Dynamic Cushioning Function Development and Validation for Polyester and Polyether Type Polyurethane Foam*, UAH Research Report No. 159, **III**, The University of Alabama in Huntsville, Huntsville, AL, 1974.

7. R. M. Wyskida et al., *Temperature Sensitive Dynamic Cushioning Function Development and Validation for Blocksom Rubberized Hair*, UAH Research Report No. 172, **III**, The University of Alabama in Huntsville, Huntsville, AL, 1975.

8. V. Kobler et al., "An Experimental Design for Total Container Impact Response Modeling at Extreme Temperatures", *Shock and Vibration Bulletin*, Naval Research Laboratory, Washington, DC, 1979.

9. R. M. Wyskida et al., *Container Cushioning Design Engineer Users Manual (HP-9815A Version)*, UAH Report No. 203, **I**, The University of Alabama in Huntsville, Huntsville, AL, 1977.

10. D. McDaniel, *Modeling the Impact Response of Bulk Cushioning Materials*, Technical Report RD-75-16, US Army Missile Command, Redstone Arsenal, AL, 1975.

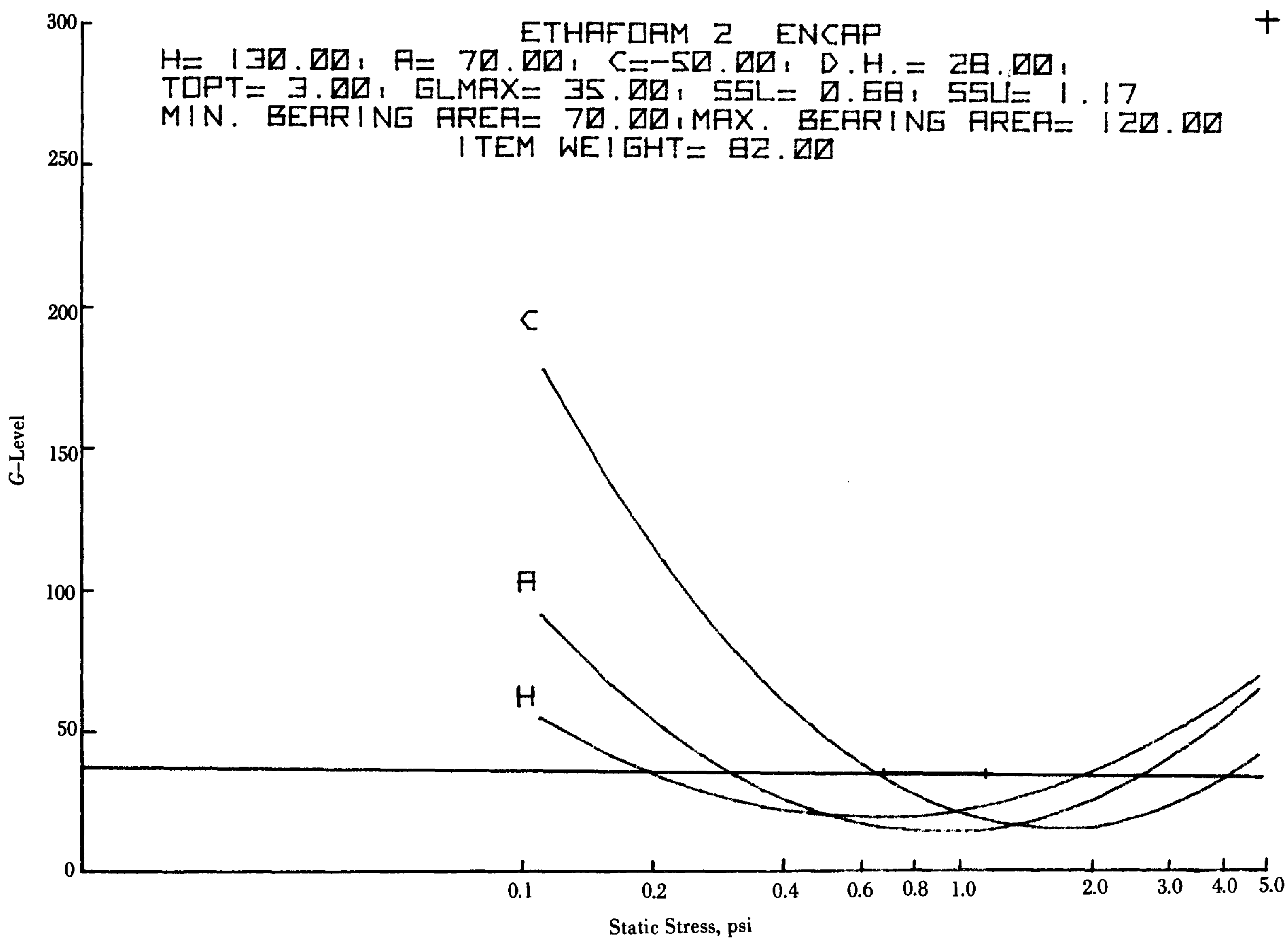



**Figure 7-46. Ethafoam 2 Encap Results for Example 4**

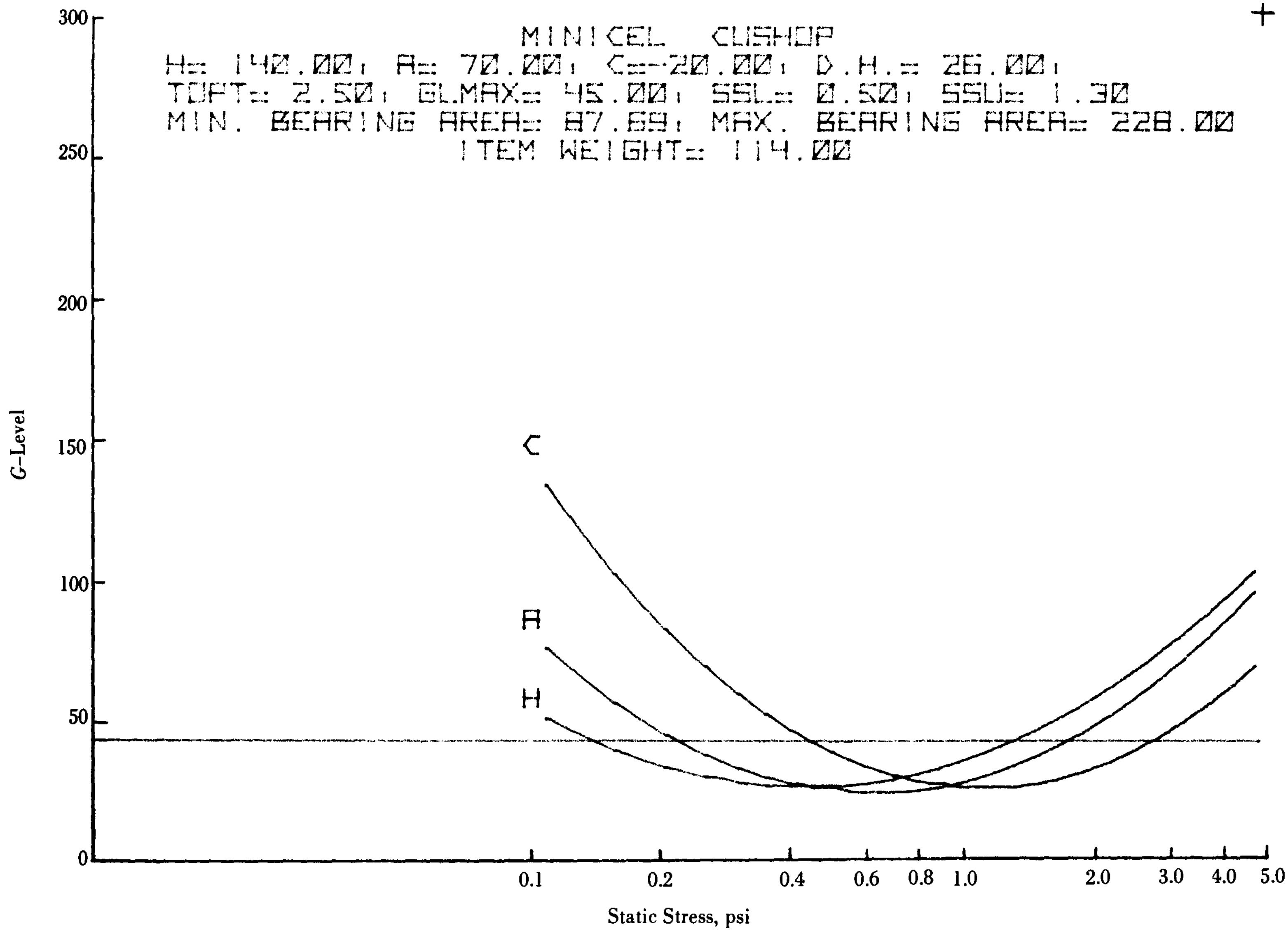



**Figure 7-47. Minicel Cushop Results for Example 5**

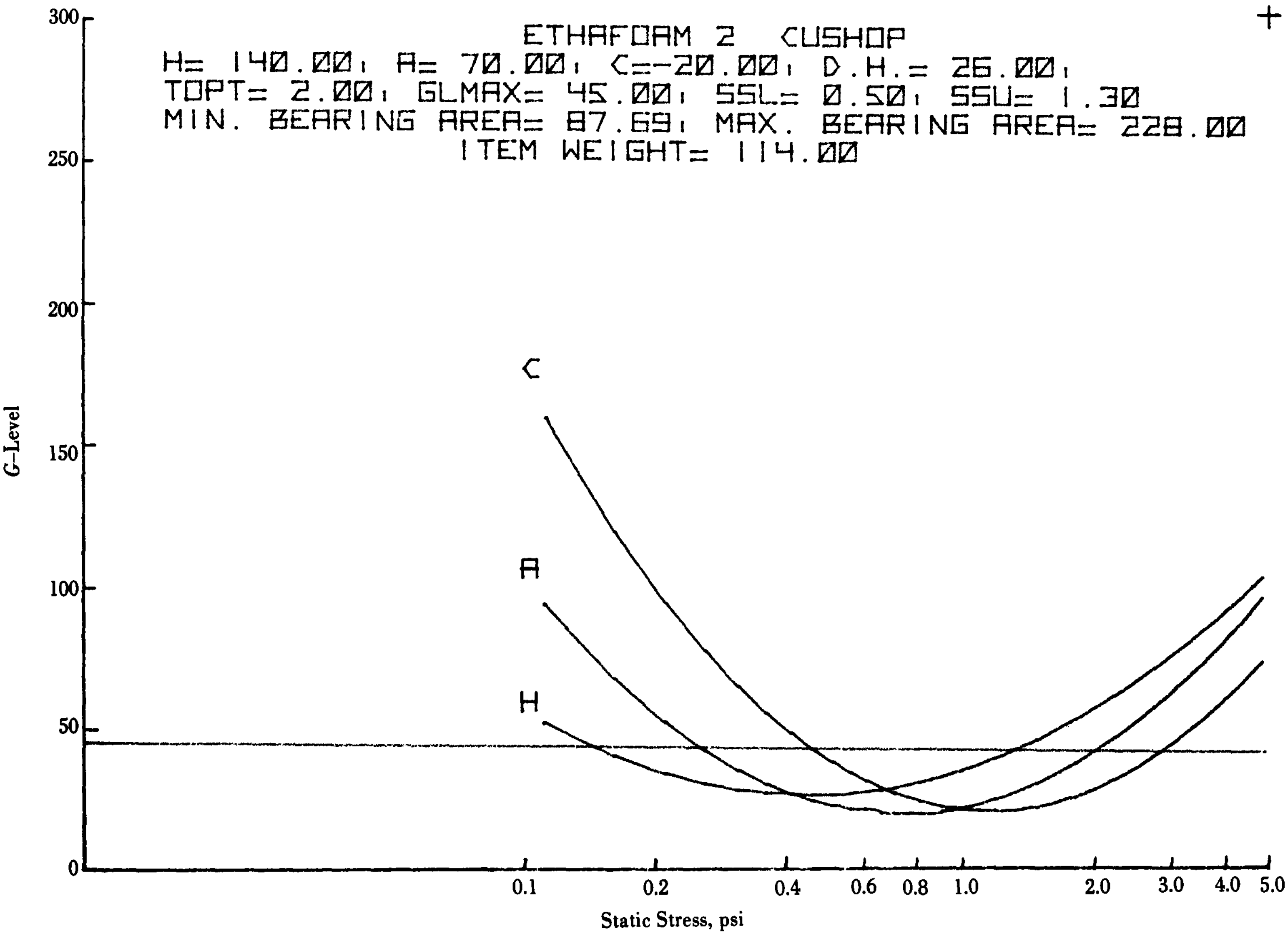



**Figure 7-48. Ethafoam 2 Cushop Results for Example 5**

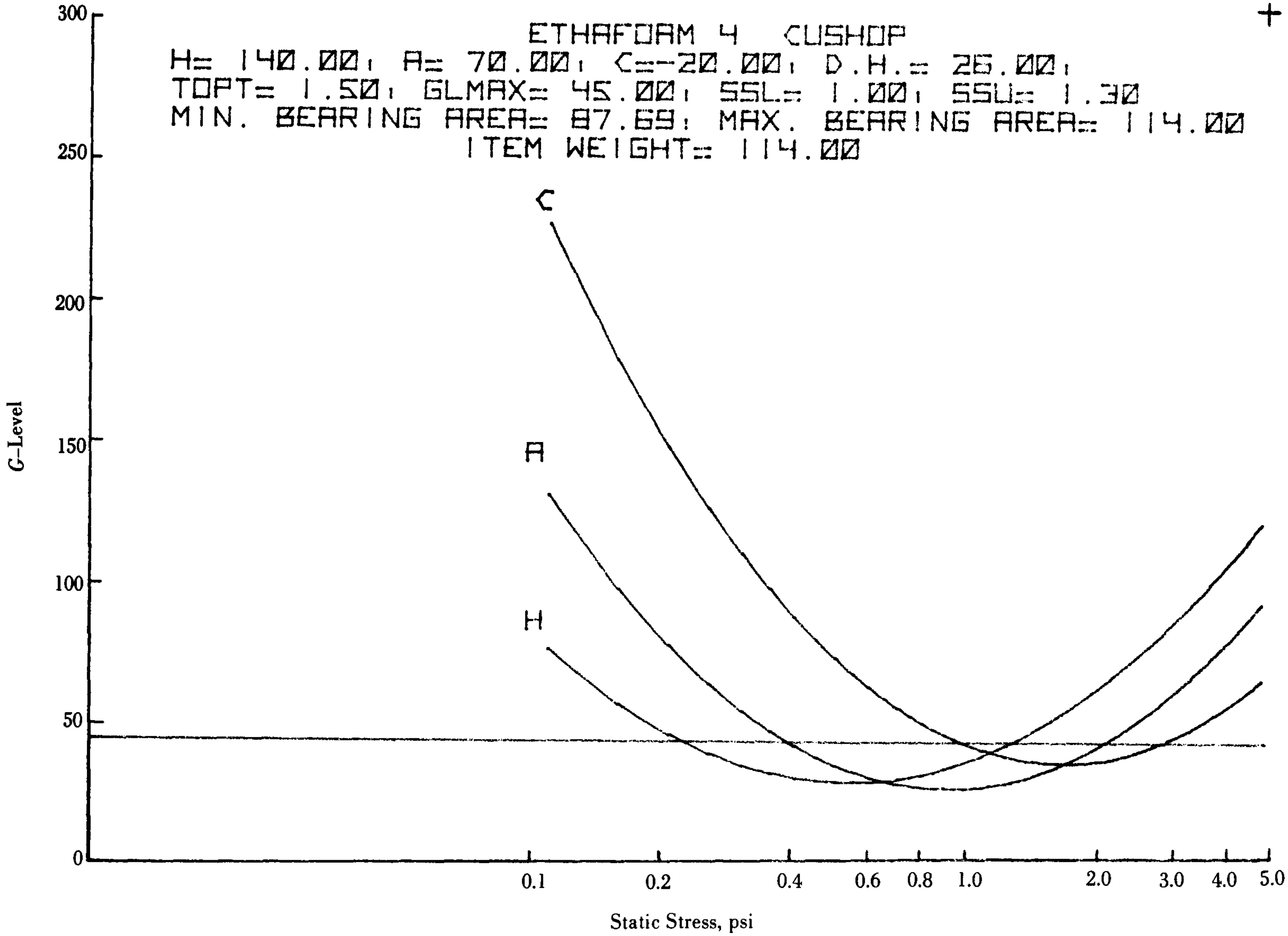



**Figure 7-49. Ethafoam 4 Cushop Results for Example 5**

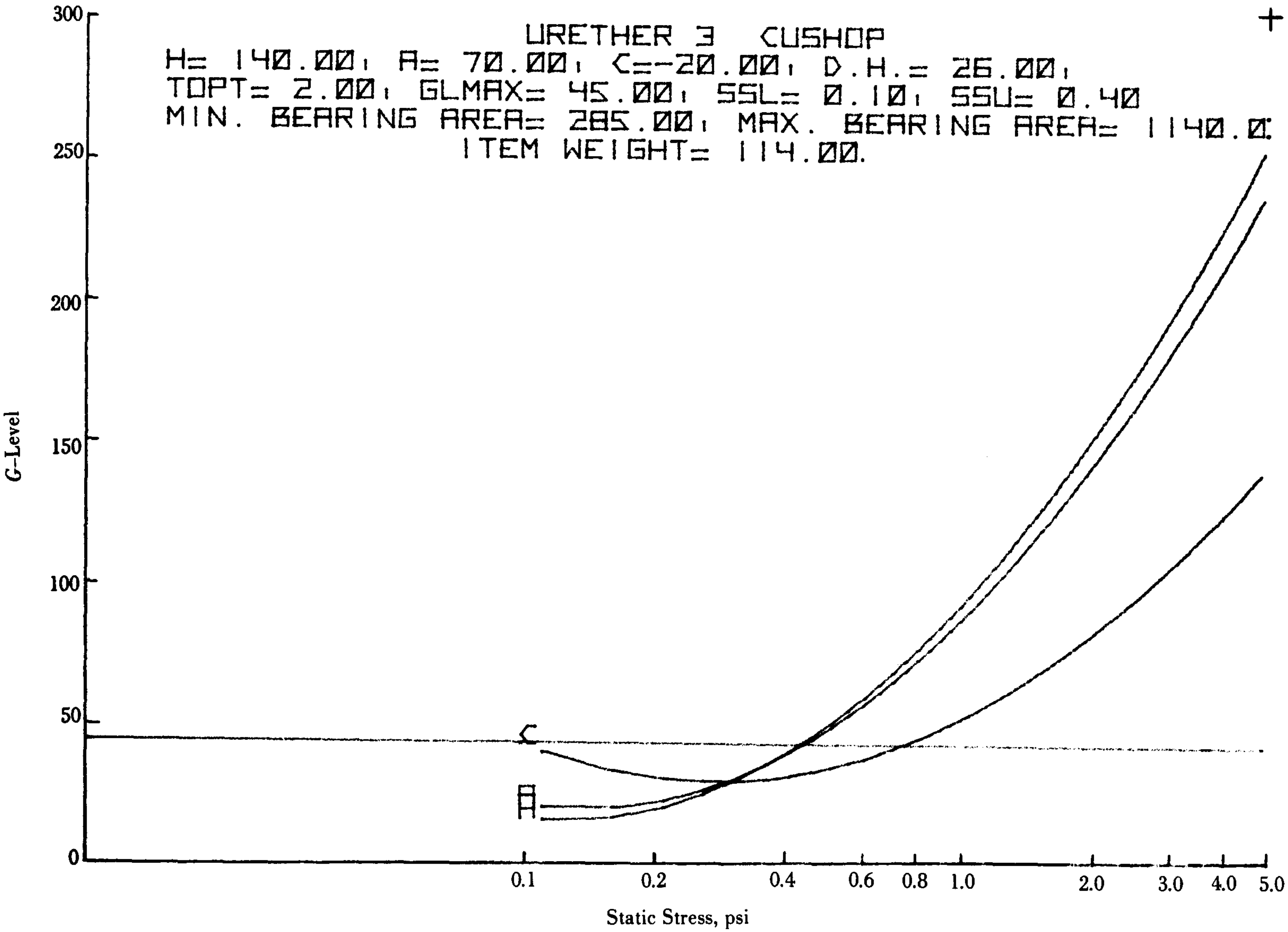



**Figure 7-50. Urether 3 Cushop Results for Example 5**

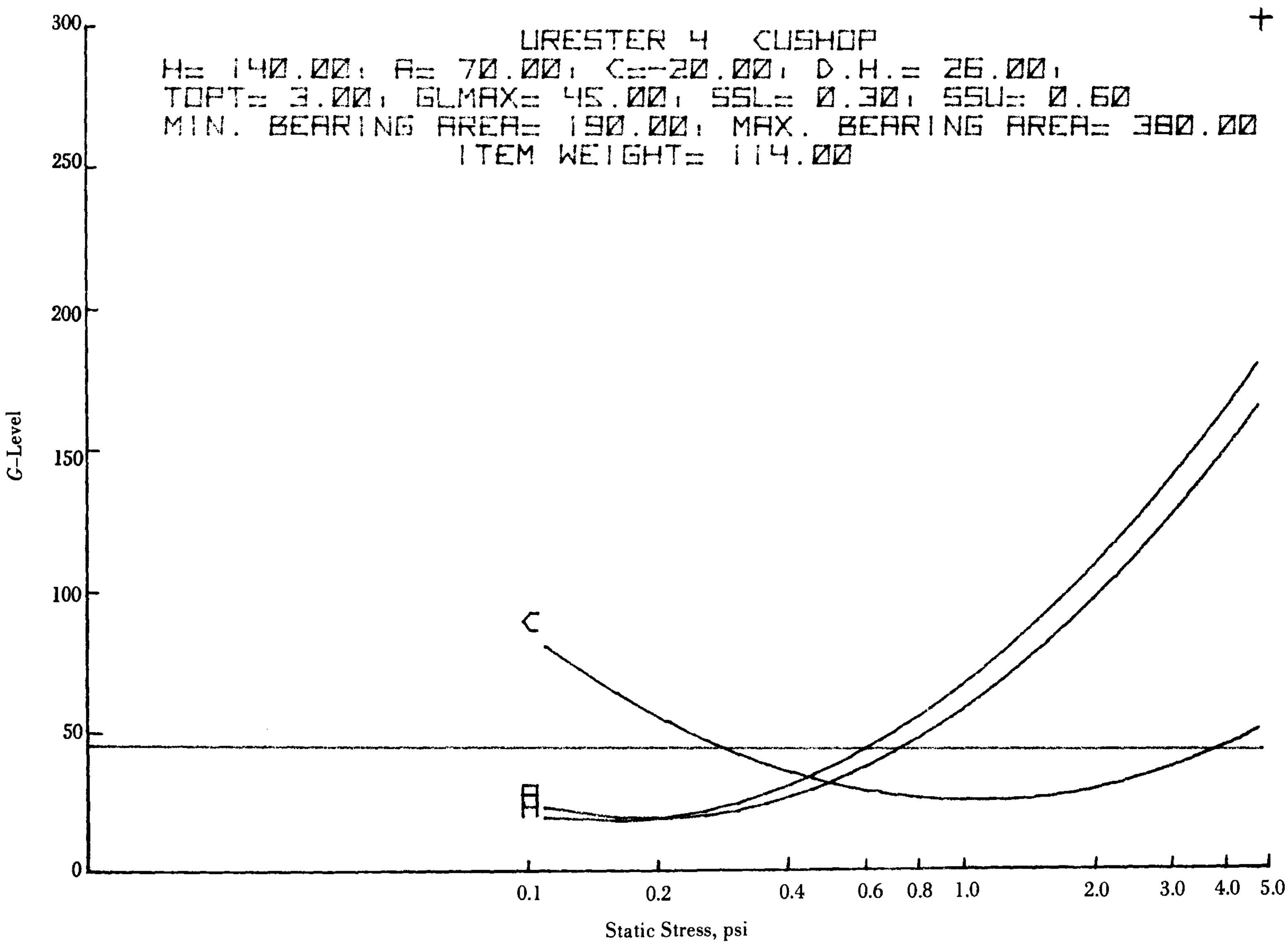



Figure 7-51. Urester 4 Cushop Results for Example 5

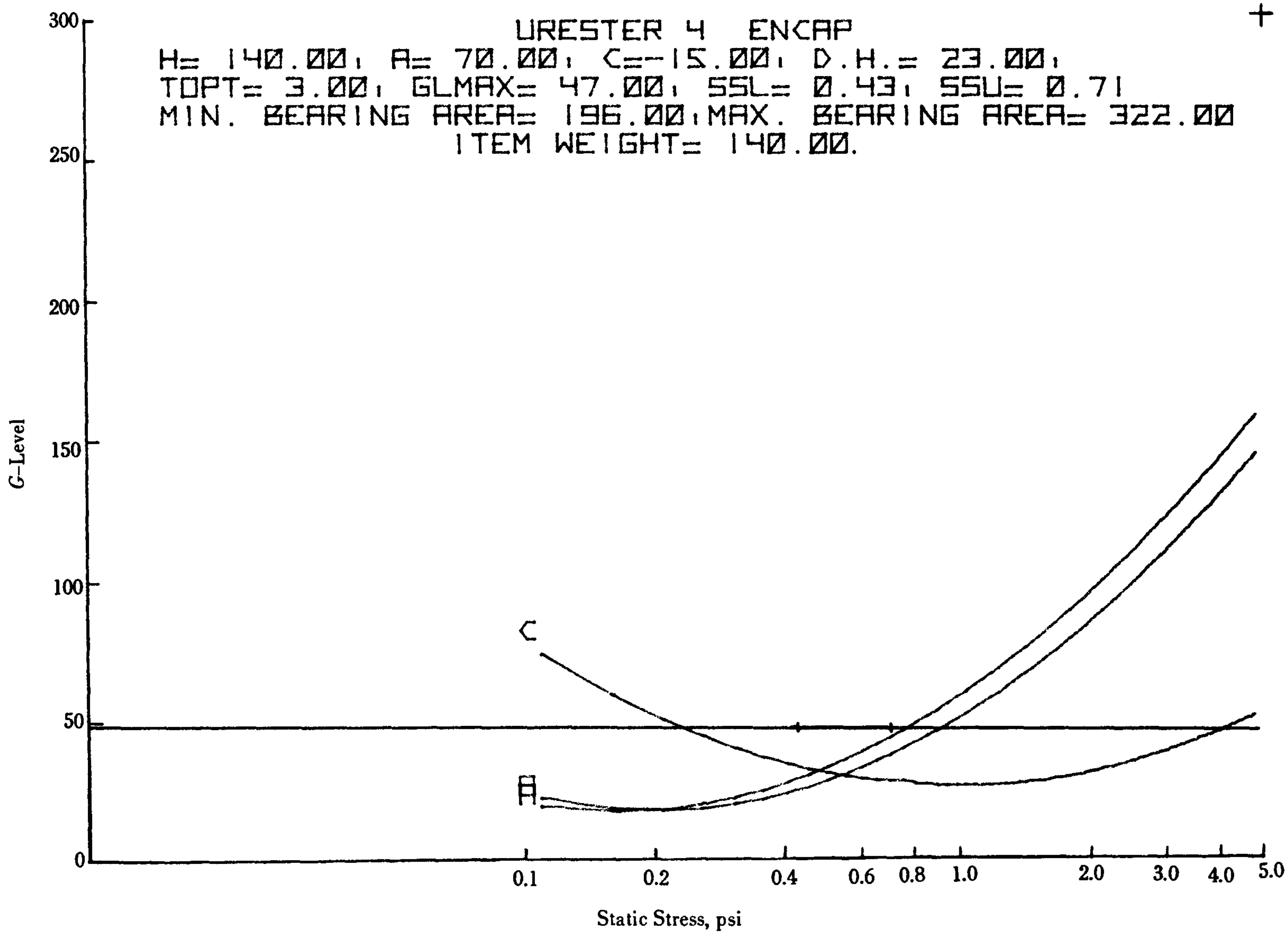



**Figure 7-52. Urester 4 Encap Results for Example 6**

# CHAPTER 8
# THE CONTAINER BODY
# TYPE—CONFIGURATION, MATERIALS, AND DESIGN

*Container body type, size, configuration, closure, and factors affecting these parameters are discussed. Advantages/disadvantages of expendable containers and module design are presented. Advantages/disadvantages of various materials of construction are outlined. Guidance on record receptacles, security seals, and data plates also are presented.*

## 8-1 GENERAL

The container body and its structural members provide an envelope to protect the suspended mass. The structural members function to support the suspension system and provide resistance to buckling and distortion. The body acts to shield the suspended mass and is often required to provide environmental protection by incorporating seals, valves, and other auxiliary devices. In addition, the body or shell may, when pressurized, be required to act as a pressure vessel capable of resisting the pressure differential of its environment. The container assembly must provide for compatibility with handling and storage operations. The complexity, configuration, size, and weight of the container must not hinder nor impede its utility; and its cost must satisfy the criterion of economic feasibility.

The primary function of the container assembly is to provide protection to its contents. The container must compensate for the inability of the missile to resist the effects of its logistic environment. Too often, the protective level of the container provides superfluous protection. Many missiles have, inherent within their design, characteristics which are capable of resisting the effects of the hazards encountered. Obviously, if the container also functions to protect against these same hazards, the container is overdesigned and the protection provided becomes superfluous. The container concept must consider the intrinsic ability of its contents and compensate for only those deficiencies pertinent to the applicable environment.

The nature of the contents to be protected dictates the size of the container. The factors affecting size are:

a. Physical dimensions of the suspended mass

b. Sway space or deflection required to protect to within the fragility level of the suspended mass

c. Suspension system and its hardware necessary to support and restrain the suspended mass.

Quite often, the capacity limitations of transit media and the human engineering factors prevalent in the logistic environment restrict the size of the container. It may be necessary to dismantle the missile assembly and house its components separately. Typical items currently housed within containers falling within the scope of this handbook include:

a. Completely assembled missiles and rockets

b. Major subassemblies of missiles and rockets

c. Loaded solid propellant motors

d. Unloaded or inert propellant motors

e. Live warheads

f. Inert warheads

g. Appendages (fins, wings, etc.)

h. Ancillary equipment.

The practice of shipping sections of large missile systems as separate items is common and quite prevalent within the Army. The many containers constituting a system may be considered a family and as such should have common characteristics. To minimize logistic support and to reduce operational complexity, those components common to containers within the same system should be identical provided their use does not degrade or compromise performance.

## 8-2 TYPES

### 8-2.1 CLOSURES

There are, within the Army missile system, two general types of containers:

a. Top or chest opening

b. End opening.

The distinguishing characteristic of the top-opening container, normally used for large missile or missile components, is the full-length cover often hinged or capable of vertical lift-off (see Figs. 8-1 and 8-2).

The end-opening type, as the name implies, includes removable ends to permit longitudinal withdrawal of the contained missile (see Fig. 8-3).

Many designs include hinged covers with spring, torsion bar, or counterweight assists; however, it has been found that these accessories merely add to the complexity of the design and complicate the logistic

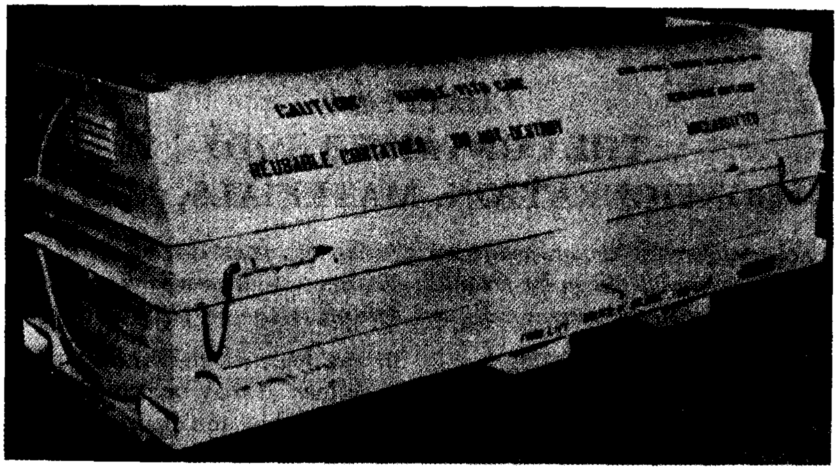


**Figure 8-1. Top-Opening Container**

support requirements (see Fig. 8-4). The size and weight of the cover are proportional to the size and weight of the contained contents. As such, it may be assumed that if handling equipment is required for content removal, the availability of such equipment precludes the need for hinges, springs, etc., to assist in manual lift of a hinged cover. Therefore hinged covers are not recommended for containers.

However, where the contents are within the weight limits established for manual handling, it may be advantageous to hinge the cover. In such instances the cover is small and lightweight and will require no complex, erratic assist mechanism.

### 8-2.2 SMALL CONTAINERS—BODY TYPES

Containers whose gross weight does not exceed 150 lb and which are capable of being handled manually may be classified as "small". Generally, the shock suspension system for lightweight contents is either simple or of the bulk cushion type, and the body structure is divorced from the need to provide localized support. Since the container can be handled manually, those accessories necessary to accommodate mechanical handling devices need not be included.

The small container may be required to provide physical and/or environmental protection. For contents whose requirements include environmental protection, an end-opening type having a shorter seal may be preferable to the top-opening type. Those containers providing only physical protection may use any of the numerous schemes currently used in military packaging.

Small containers may be considered as sophisticated packages and subject to the techniques applicable to military packaging adequately documented in existing DOD publications. TM 38-230-1, *Packaging of Materiel, Preservation (Volume 1)*, is typical of the many documents providing guidance in packaging technique.

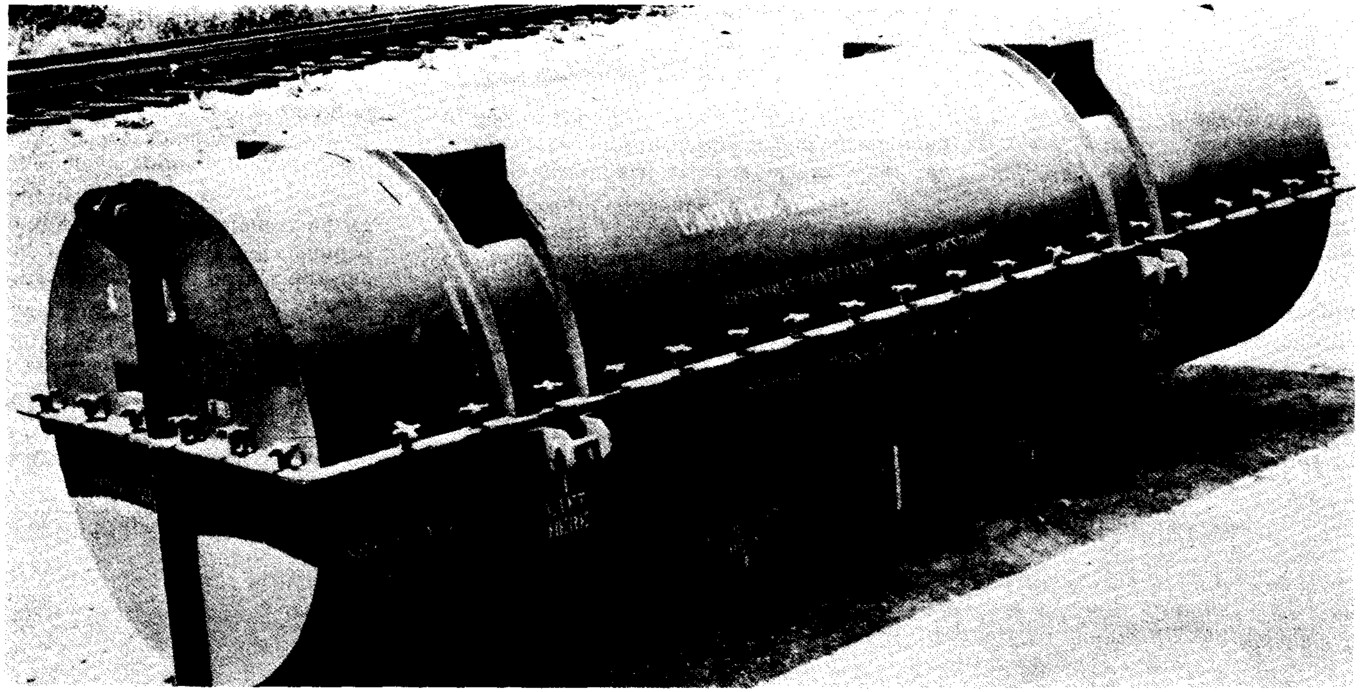
Figs. 8-5, 8-6, and 8-7 illustrate small containers.

## 8-3 FACTORS AFFECTING CONTAINER BODY SIZE

The container size is determined primarily by the envelope of the missile or missile component, missile fragility level, and missile weight and weight distribution.

The principal factor affecting the size of the shipping container is the envelope of the suspended mass. As a general rule—ignoring clearances required for shock and vibration isolation purposes—a container of modest, size, i.e., less than 5 ft in any dimension, may be expected to be at least 2 in. greater in outside dimensions than the envelope dimension of the contents. For larger size containers, where significant structural strength must be built into the container, the minimum increase in overall exterior dimensions is on the order of 1 ft.

It should be noted that the dimensions discussed are concerned with the maximum dimensions of the contents. In the case of completely assembled missiles, the overall wing span and not the body diameter must be considered as the basic limiting dimension for the proposed container. The cushioning clearances required are determined by the most delicate components of the complete assembly; therefore, the clearances required for the complete missile are considerably more than would be required for a majority of the individual components.



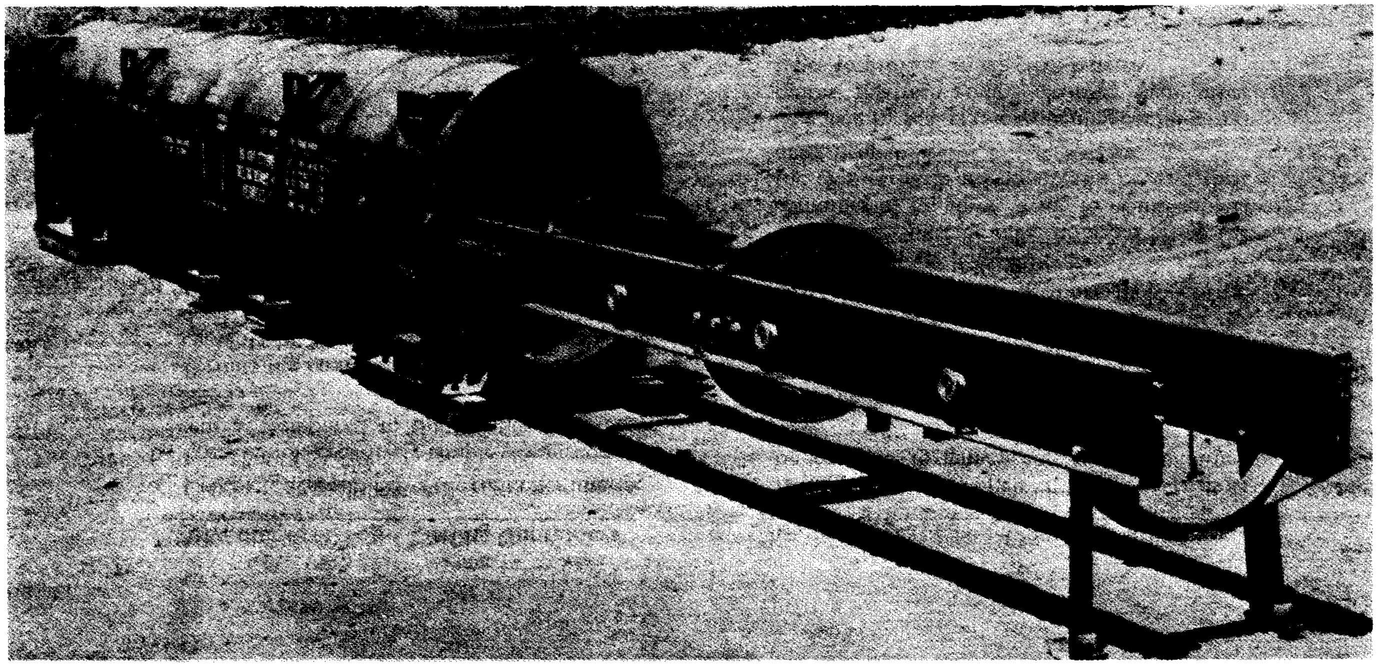
**Advantages of Top-Opening Containers**

a. Complete accessibility of the container interior
b. Provides for a relatively simple suspension system as compared to that required for other types
c. Permits the convenient manual removal of the contents or by any available overhead lifting device
d. Accessibility to all portions of the container interior facilitates maintenance and repair
e. The design requires less cubage, resulting in less overall weight and consequently is less costly than other types.

**Disadvantages of Top-Opening Containers**

a. A large, heavy and often unwieldly cover must be removed to gain access to the contained item.
b. Top-opening containers separate longitudinally and require a longer seal when such a barrier is required. Since the effectiveness and reliability of a seal varies with its length, the design of the seal joint becomes more critical with an increase in length.
c. Precautions must be taken to avoid lifting the container by its cover; to do so would subject the closure hardware to stresses beyond their design capability.
d. The lengthy seal of a top-opening container requires relatively more closures than other types to provide an effective barrier.

**Figure 8-2. Typical Top-Opening Container (Note excessive number of closures.)**



### Advantages of End-Opening Containers

a. The seal is simplified and more effective by virtue of its relatively short length.

b. Less closure hardware is required.

c. End covers are small and easily handled as compared with the large unwieldly covers of top-opening containers.

d. The container may be lifted from either the top or bottom with the only restriction limited to the removable end or, in containers longer than 5 ft, both removable ends.

e. End-opening containers, due to their configuration, provide a shield to both their contents and to their interior to resist penetration of rain, snow, etc., even when the ends are removed.

### Disadvantages of End-Opening Containers

a. The need for a complex suspension mounting system results in a considerable weight penalty and introduces a complex, erratic mechanism.

b. Increased maintenance costs result from the need for a complex, telescopic, roll-out suspension system.

c. Malfunction of the suspension support structure would prevent access to and removal of the container contents.

d. The longitudinal removal of the contained missile requires the availability of often limited floor space.

e. Auxiliary bipods or struts are required to support the cantilevered missile.

f. Longitudinal transfer of the load CG results in a lack of stability with tipping over a potential safety hazard.

g. Complexity of design requires excessive logistic support.

h. The complexity of the support mechanism introduces potential areas of failure and compromises performance reliability.

**Figure 8-3. Typical End-Opening Container**

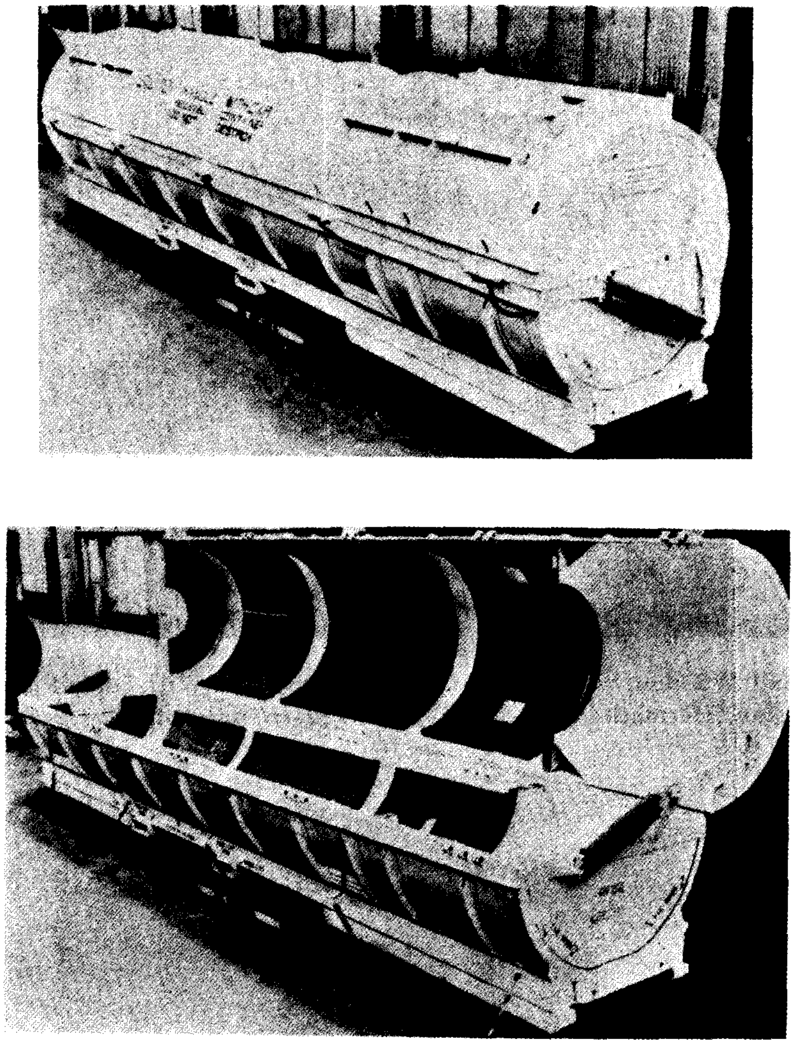


**Figure 8-4. Hinged Cover With Spring Assist**

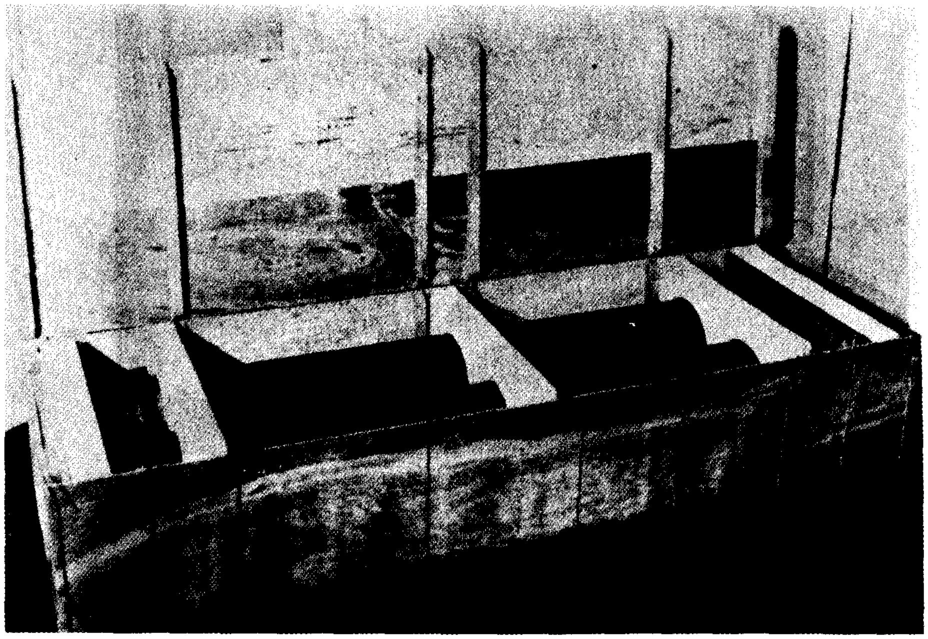


Figure 8-5. Small, Wooden, Wire-Bound Overpack Container With Foam Plastic Yoke-Type Suspension (Hermetically sealed contents require only physical protection.)

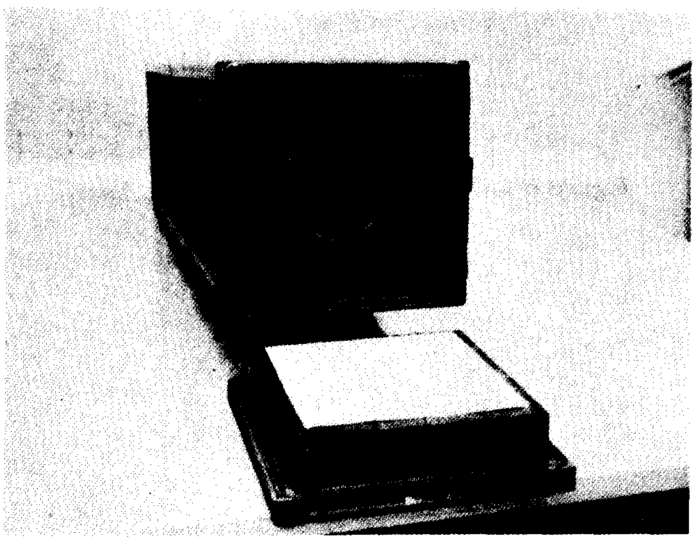


Figure 8-6. Small, End-Opening, Sealed Container With Fiberglass Cushion Suspension

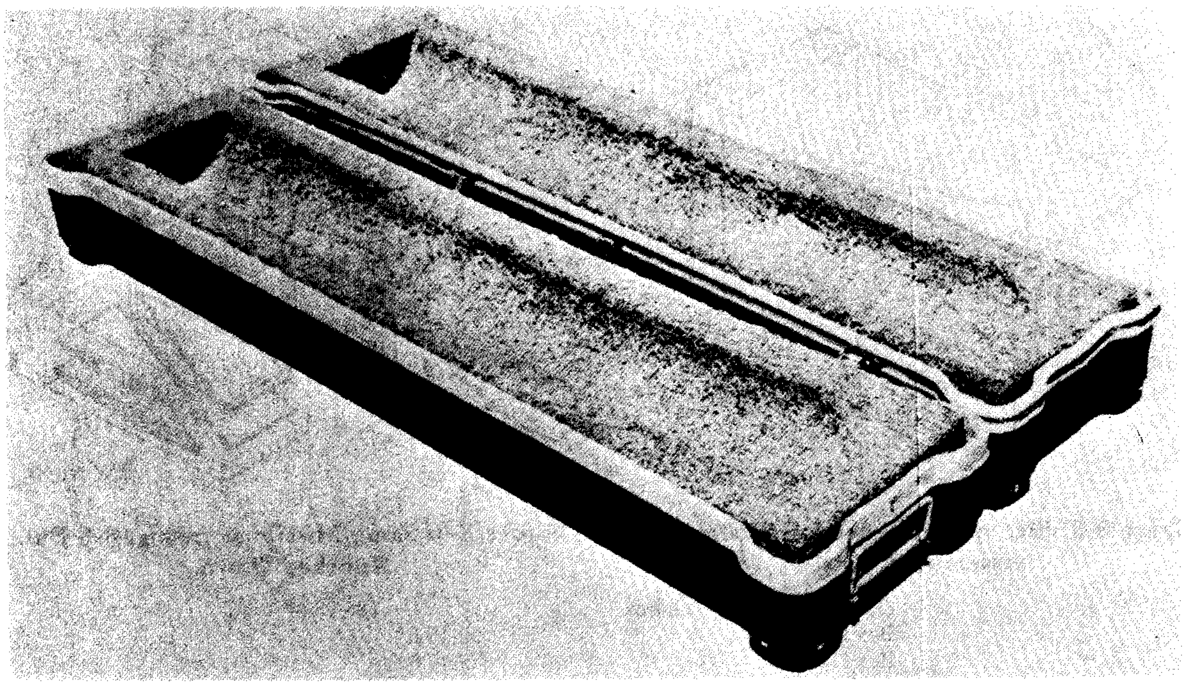


**Figure 8-7. Small, Sealed, Hinged-Top Container With Curled Hair Cushion Suspension**

Early consideration of disassembly for shipment is of paramount importance. For example, assume a missile 7.3 ft long and equipped with cruciform airfoils with a 4-ft span, no portions of which may be disassembled after checkout. If a 6-in. deflection is allowed for the suspension system to protect delicate components, a shipping container like that illustrated in Fig. 8-8 will result.

If the missile can be disassembled into three major groupings, it is possible to obtain a 75% reduction in cube size. In examining Fig. 8-9, it will be noted that the 6-in. clearances for the delicate guidance section have been maintained, but the more rugged warhead and the very rugged airfoils can be packaged in containers of considerably smaller size and complexity. While the savings shown in the foregoing example may be somewhat high, 50% cube reduction often is easily achievable. The necessity for intelligent planning of the missile design to permit partial disassembly for shipment (particularly removal of protruding airfoils and antennas) is obvious.

In planning for disassembly, however, the following points—as well as orderly arrangement in the container—also must be considered:

a. Field reassembly conditions—such as tools, fixtures, and skills available

b. Boxing arrangement which permits reassembly in logical sequence

c. Boxing arrangements compatible with deterioration prevention requirements

d. Segregation of explosive and dangerous components.

The second most important factor determining overall size of the shipping container is the fragility level of the missile or missile component under conditions of storage, shipment, handling, or test.

The third factor which affects the size of a shipping container is the missile weight and weight distribution. The content weight directly affects the container in the following ways:

a. It limits the styles of containers which may be selected.

b. Within a selected style, it has a major controlling influence on the sizes of container members and the types of joints.

c. Through its major effect on gross weight, it influences transportation cost.

d. It controls the type and capacity of shock and vibration isolation system selected.

e. It establishes handling requirements, manual or mechanical, and the size and location of handling fittings on the container.

f. If it is assumed that the cubage is within transportation limitations, it determines the number of items which may be transported by any given transportation unit—i.e., single airplane, railroad car, or

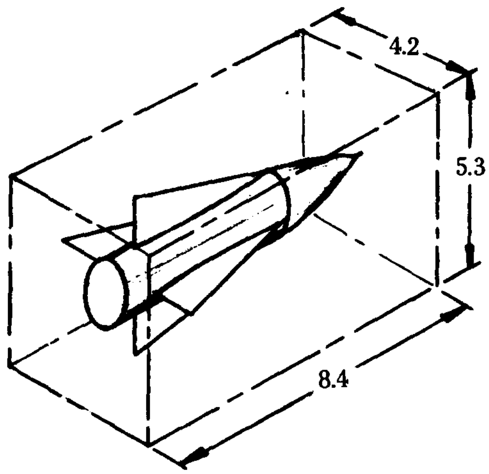



**Figure 8-8. Size of Container for a Completely Assembled Missile**

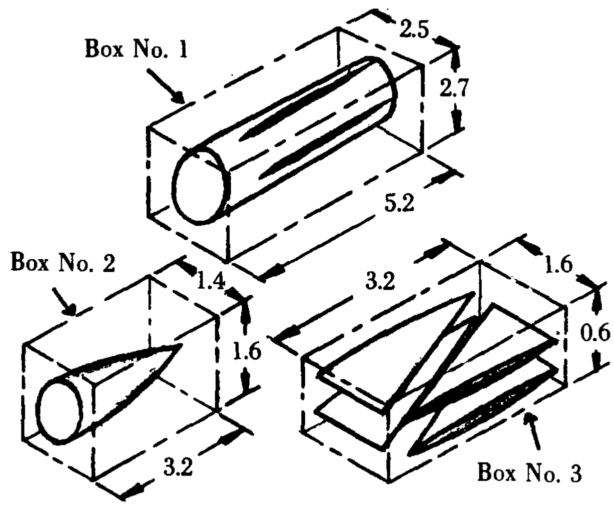



**Figure 8-9. Same Missile as in Fig. 8-8 But Knocked Down**

| | | |
|---|---|---|
| Completely assembled box | | 186.98 ft³ |
| Box No. 1 | 35.10 ft³ | |
| Box No. 2 | 7.17 ft³ | |
| Box No. 3 | 4.61 ft³ | |
| Total for K/D shipment (25% comp. assy box) | | 46.88 ft³ |
| Cube saved (75% of comp. assy box) | | 140.10 ft³ |

truck, and the number which can be put in any given storage space.

The weight distribution of the missile or missile component affects the container in the following manner:

a. Through the interrelation of weight distribution and missile size, it affects the overall size of the container, thus limiting the choice of container style.

b. It determines the size of container members. For example, for any given style of conventional container, the member sizes vary depending on whether the contents are an easy, average, or difficult load. An easy load is an item which has low or moderate density conforming to the shape of the container, thus lending support to the container. An average load is an item which has low or moderate density and which, when packed directly into a shipping container, provides nonshifting support at several points in the container. A difficult load is an item characterized by irregular shape which does not lend support to the container or characterized by great density, great bulk, or extreme fragility.

c. Weight distribution is of paramount importance in the design of the shock and vibration isolation system.

## 8-4 FACTORS AFFECTING CONTAINER CONFIGURATION

The lateral cross section of the missile container may be in the form of any of the common geometric configurations or a composite of these basic forms. Many are basically round; others are square; and elliptical cross sections are quite common. However, in almost all containers, regardless of the basic configurations, the outer envelope periphery will invariably be square or rectangular. The square or rectangular form is most compatible with economical cubing patterns and provides stacking stability.

The nature and size of the suspended mass and its shock mitigating suspension affect the overall configuration. In addition, the material and the optimum fabricating methods peculiar to the material also contribute to the final shape of the container. In isolated cases, it may be necessary to apply pressure vessel design technique to withstand the effects of pressurization. There are numerous factors which must be considered in establishing an optimum container configuration; these include:

a. Size and nature of the proposed contents
b. Sway space requirements
c. Suspension system support requirements

d. Pressurization requirements if applicable
e. Need for providing environmental protection
f. Field maintenance requirements
g. Disposition of container—reusable or disposable
h. Material and its characteristics
i. Fabricating techniques peculiar to the material used
j. Projected quantity requirements affecting manufacturing process
k. Logistic requirements for stacking, hoisting, and handling
l. Human engineering factors
m. Cost limitations based on function as dictated by value engineering techniques.

A typical container lateral cross section would be a composite of conventional geometric configurations. The elongated elliptical body would be supported by a series of rectangular trusses modified to include round corners for effective roll-over performance. The number of trusses would vary with length and provide characteristics that result in optimum cubing and stacking patterns.

Figs. 8-10 through 8-16 show typical containers and stacking arrangements.

## 8-5 MODULAR DESIGN

In an attempt to reduce costs by standardization, modular design concepts have been developed which provide versatility and result in expeditious container procurement. The concept is based upon the use of common standard components; in particular, cast corners and extruded edges having the capability of accepting side panels whose size may be varied to satisfy the container spatial requirements. MIL-C-22433 delineates the requirements of this concept and establishes the scope of application. Fig. 8-17 depicts a modular container and its method of fabrication.

The economic feasibility of the modular concept is based on its versatility and the need to stock only a minimum assortment of basic parts. The availability of these building blocks can satisfy the demands of both limited and high volume procurement requirements.

The technical feasibility is limited, within the scope of this handbook, to the small container field since the variable side panels are not capable of supporting localized stress concentrations without auxiliary bracing. In addition, the need to caulk, bond, or weld the various components into an assembly capable of resisting climatic exposure limits its application. Thus any degree of climatic protection provided becomes marginal. Consequently, the modular design is recommended for small container applications whose contents can survive in a free or controlled atmosphere.

A modification of the modular concept makes available a knockdown feature which provides economy in the return shipment of empty reusable containers. Due to their nature, these containers are not suitable where prolonged climatic exposure will prove detrimental. Consequently, the use of the knockdown concept should be limited and restricted to materiel inert to climatic exposure or to shipments exposed to only a controlled environment.

## 8-6 EXPENDABLE CONTAINERS

The modern, mobile army operating in a hostile environment in the field should not be required to perform salvage and reclamation functions which will impede its "shoot-and-scoot" capability. Unfortunately, today's missiles and many of the rockets currently available to the Army are highly sensitive and require a level of protection which makes necessary the sophistication found in the majority of protective containers. The cost to provide this level of protection makes mandatory the reuse of these items; many of which are in essence climatic chambers.

The demands of the tactical environment and those relating to economic feasibility are diametrically opposed and present a paradox which the container designer must recognize and resolve to the satisfaction of both the field commander and the logistician. Obviously, the designer must be prepared to make trade-offs without sacrificing the physical and protective integrity required of the container.

The integrity of the missile and/or rocket cannot be compromised; its reliability is paramount. This tenet is basic to the field of container technology and is not subject to negotiation or trade-off. However, the designer is provided sufficient latitude in the selection of materials, configuration, etc., to provide an optimum container whose cost will be consonant with its function.

The container designer must be cognizant of the military requirements pertinent to the overall weapon system and establish as his goal the development of an expendable container. The connotation associated with "expendable" is low cost, and the result of the development effort must be an inexpensive container. The cost analysis of any container should consider, in addition to initial procurement cost, the following factors whose sum represents actual cost:

a. Final assembly costs
b. Maintenance costs

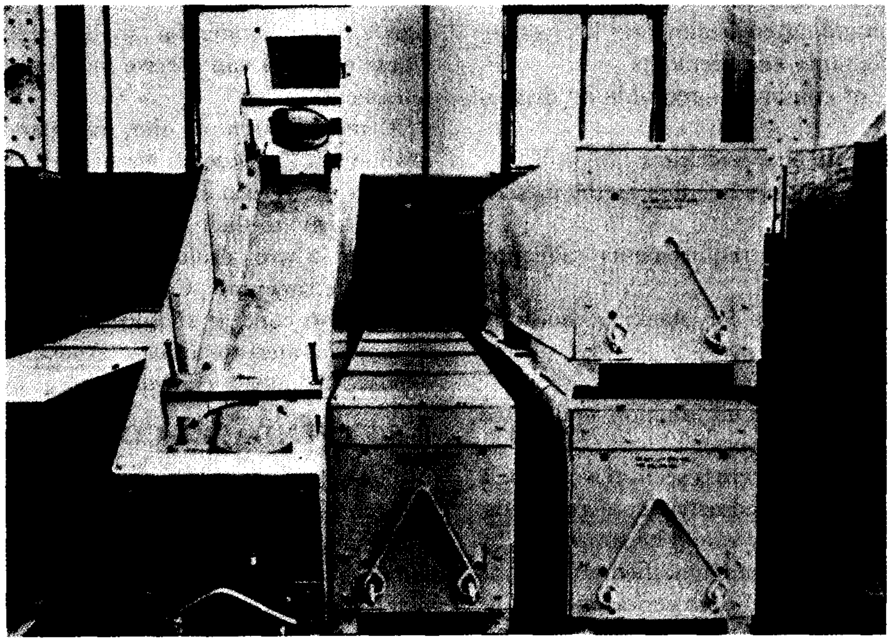


Figure 8-10. Reinforced, Wooden, Free-Breathing Rectangular Container

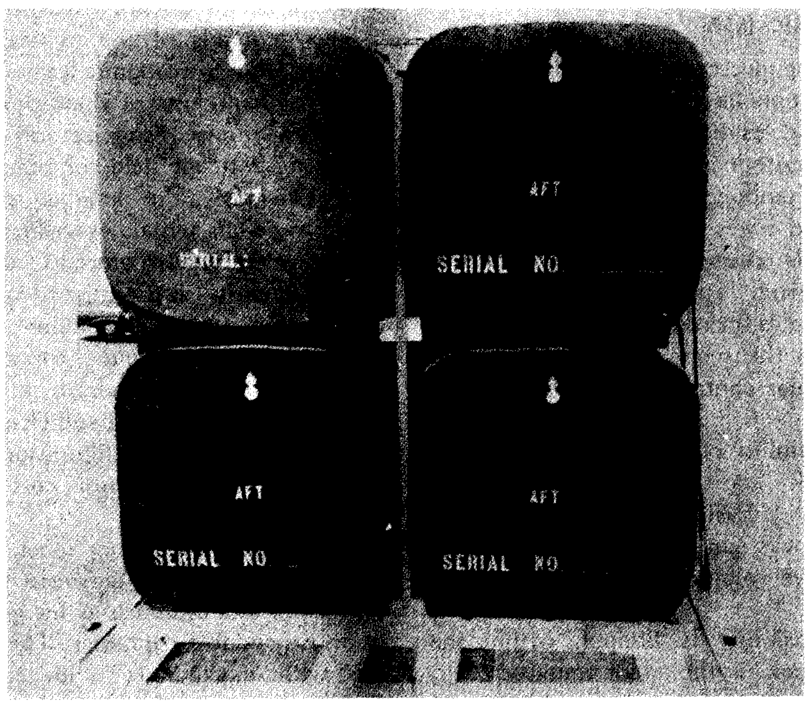



Figure 8-11. Steel, End-Opening, Controlled-Breathing Rectangular Container Equipped With Stacking Pads, Skids, and Modified Corners

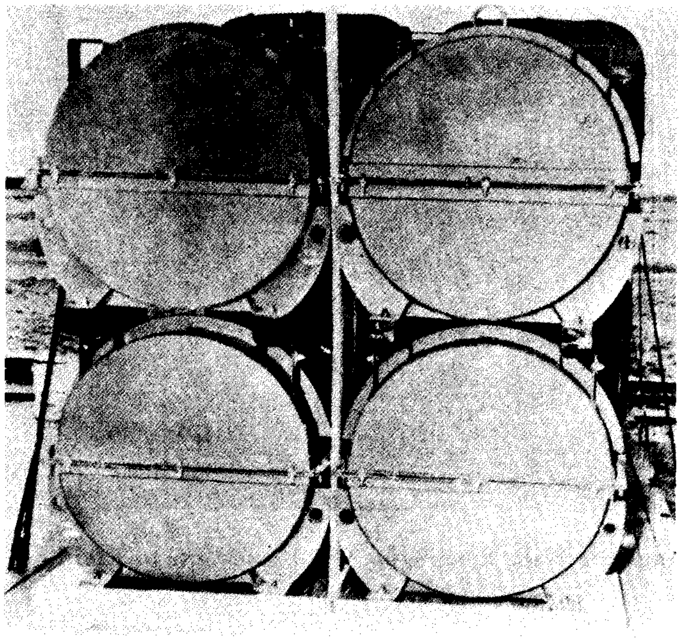


Figure 8-12. Steel, Chest-Type, Round Container With Stacking Pads and Skids Forming Rectangular Periphery

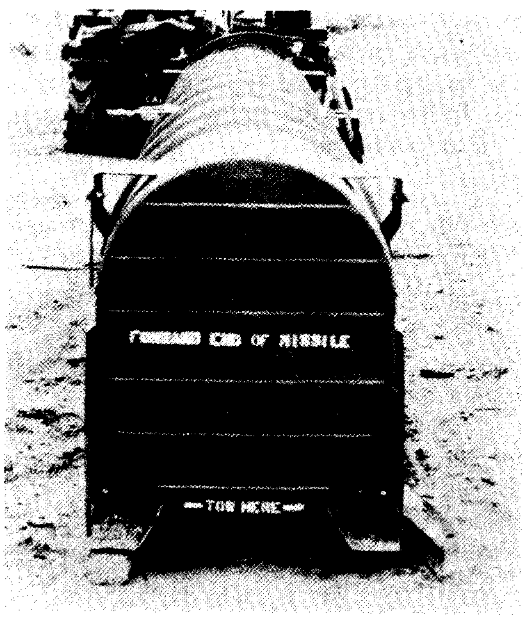



Figure 8-13. Pressed Steel, Ribbed Modified Elliptical Container With Stacking Pads and Skids to Provide Rectangular Periphery

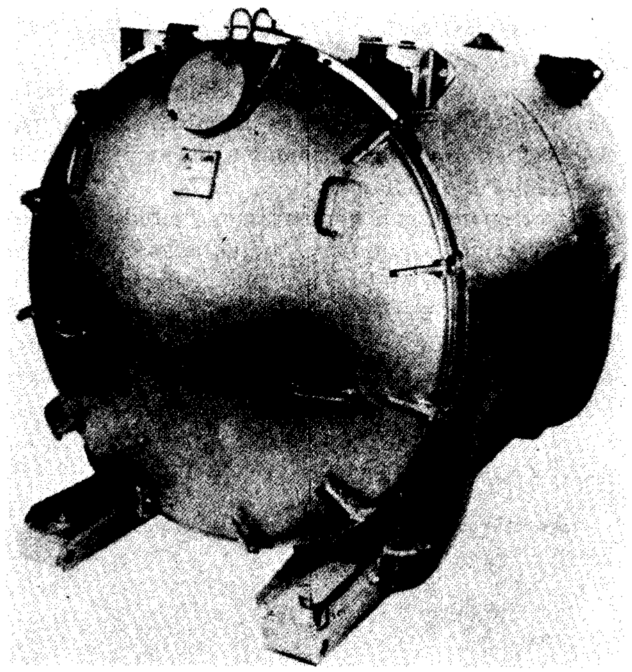


Figure 8-14. Rectangular Configuration Provided by Stacking Pads and Skids

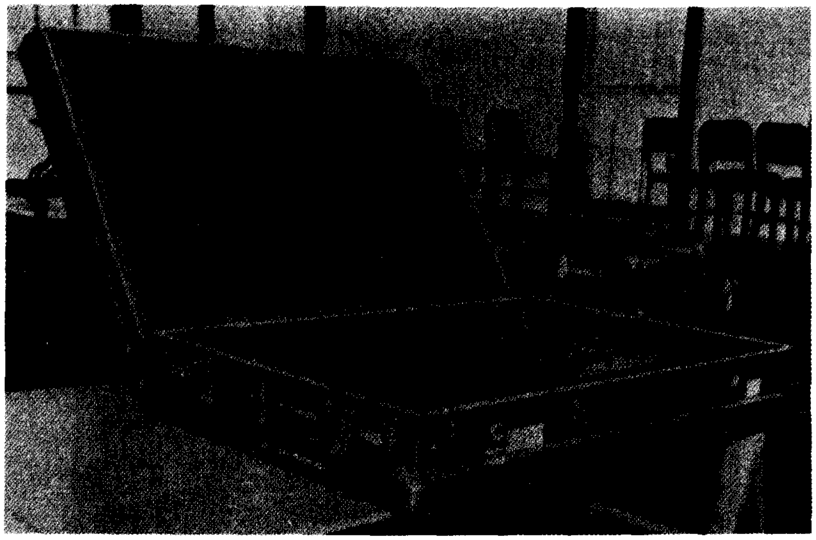


**Figure 8-15. Fin Container With Rectangular Cross Section to Facilitate Cubing and Stacking**

c. Cost to compensate for container limitations necessary to qualify for worldwide distribution

d. Return shipping costs

e. Reconditioning costs

f. Secondary use at point of destination—a value that can be credited to the overall cost.

A review of these contributing factors will then permit classifying the container as either reusable or expendable.

In many instances, overdesign contributes most to the need to classify a container as reusable. Too often the cost to supply superfluous protection prohibits disposal of the container.

Unfortunately, it is impossible to establish rules for classification. In summary, the designer must practice good design and be prudent in the selection of materials and components. The principles of value engineering must be applied and the result of the development effort evaluated to determine the economic feasibility of disposal versus reclamation.

## 8-7 CONTAINER BODY MATERIALS

The five materials most commonly used in container body contruction are:

a. Steel

b. Aluminum

c. Wood

d. Plastic

e. Fiberboard.

In addition to these, sandwich material comprised of aluminum, wood, or plastic or any of these in combination are being used in container construction. Use of this fabricated material results in high cost; however, where weight to strength ratio is critical, the use of this sophisticated material may be justified. Table 8-1 provides a guide to the selection of materials.

Selection of the material to be used is dependent upon many factors, in particular, those peculiar to the operating environment and those characteristics of the material affecting structural load bearing capacity. In addition, the ability to resist penetration and the durability of the material must be considered.

As a rule, the container designer should consider the following when selecting a material:

a. Ability to provide the level of physical protection required

b. Ability to resist penetration both physical and environmental

c. Compatibility of material with its contents to avoid deterioration by galvanic action, chemical exposure, etc.

d. Density as affecting overall weight

e. Ability to support suspension system

f. Structural capacity to resist buckling

g. Availability during time of hostility

h. Ease of field maintenance and repair

i. Fabricating characteristics and the economic aspects of manufacture

j. Cost relating to both small production lots and those of mass production

k. Utility of end-item—reusable or expendable.

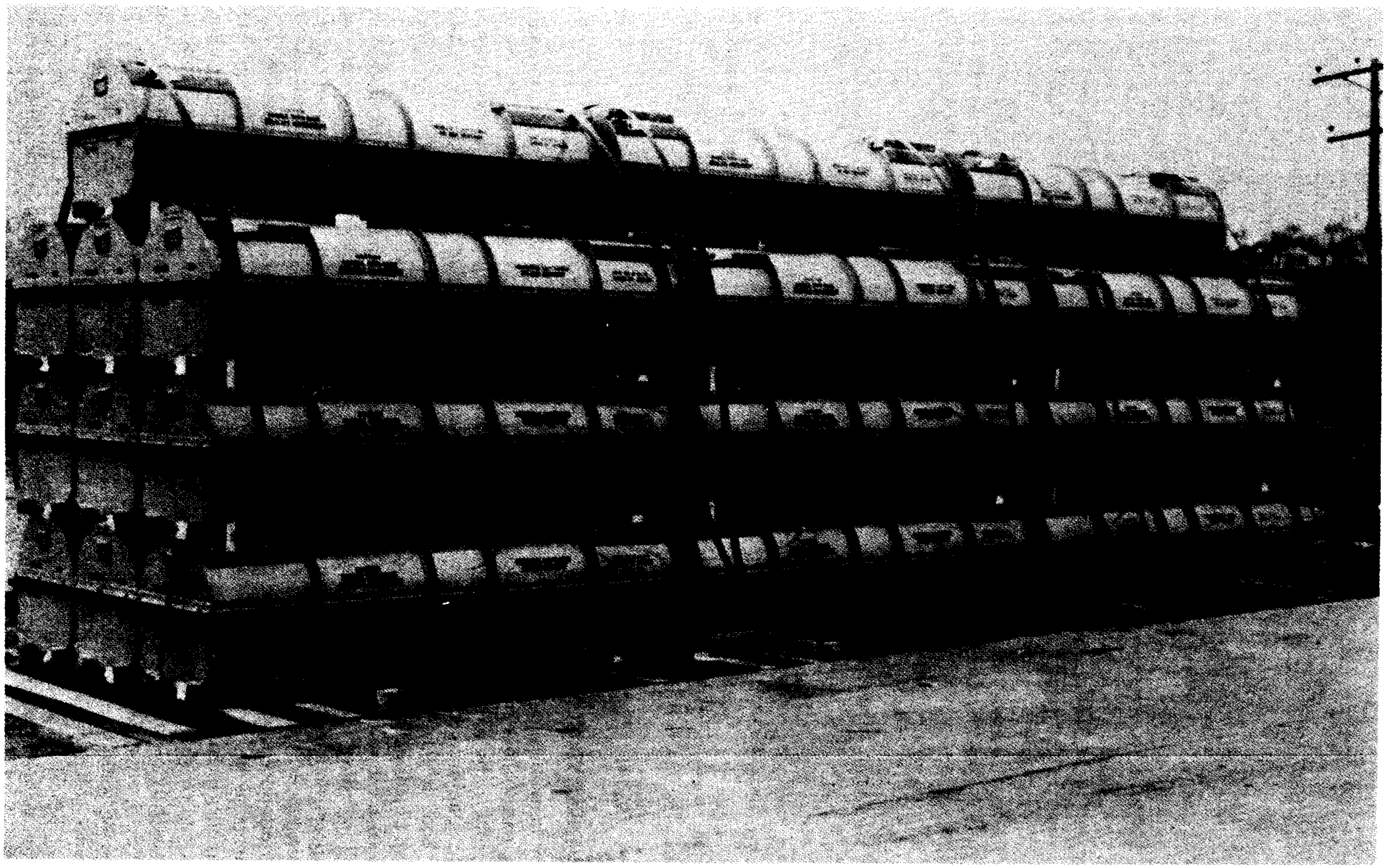


Figure 8-16. Typical Stacking Pattern—Container Structure Must Resist Vertical Loading

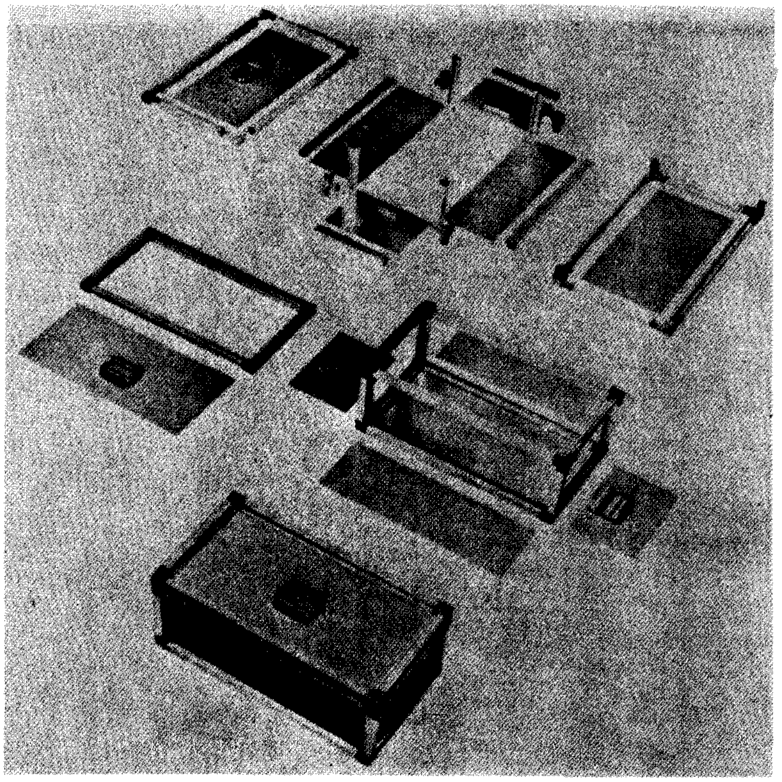


**Figure 8-17. Modular Design Container**

## 8-8 SELECTIVE SALVAGE

The fragility of many missiles is often of a level requiring complex, costly shock mitigating devices. In some instances, this is the only protective requirement and the use of an inexpensive wooden or fiberboard container body is permissible. The container body as such, can be considered expendable due to its relatively low cost. However, the cost of the container assembly, including the suspension system, prohibits its disposal and often dictates that it be reused. In such instances, the technique of selective salvage can be introduced which permits the expensive components to be stripped from the container and returned as reusable components. This practice reduces return shipping costs and affects only those items worthy of salvage.

The designer can apply the selective salvage technique and the use of flexible barriers to wooden and fiberboard container design to result in an assembly providing both physical and climatic protection which can qualify as being expendable, subject to disposal after "one-shot" use.

## 8-9 FLEXIBLE BARRIERS

The conventional missile container, in addition to supporting and physically protecting its contents, is often required to function as a barrier to resist the transmission of liquid water and water vapor. The designer can, by selecting the proper materials, satisfy both requirements.

Steel, aluminum, and plastic provide excellent resistance to the transmission of liquid water and water vapor and, when used in conjunction with effective seals, provide a container having both the required rigidity and climatic resistance necessary to satisfy the protective and handling requirements. However, the use of these materials and the fabrication methods peculiar to their application result in relatively high cost. Consequently, the developed container by economic necessity is classified as reusable and subject to the reclamation processes discussed in previous paragraphs of this chapter.

In many instances, particularly in small containers, the designer can divorce the need to resist moisture penetration from the container body and assign

## TABLE 8-1
## CONTAINER BODY MATERIALS — SELECTION GUIDE

| Material | Advantages | Disadvantages |
|---|---|---|
| Steel<br>See:<br>Fed Spec QQ-S-698<br>Fed Spec QQ-S-741<br>MIL-S-13281 | a. Adaptable to large volume, low cost production<br>b. Excellent resistance to moisture-vapor transmission<br>c. Excellent adaptability to pressurization of container<br>d. Excellent fire resistance<br>e. High strength<br>f. Ease of repair<br>g. Long life when properly finished<br>h. Highly resistant to physical penetration<br>i. Excellent structural rigidity | a. Use of steel results in high weight<br>b. Subject to corrosion unless treated or finished |
| Aluminum<br>See:<br>Fed Spec QQ-A-250/11b<br>Fed Spec QQ-A-200/9<br>MIL-C-22443 | a. Lightweight<br>b. Noncorrosive<br>c. Adaptable to modular construction and mass production | a. Easily damaged<br>b. High maintenance costs<br>c. Cannot be conveniently repaired in field<br>d. Welds and sealed joints tend to crack and leak |
| Wood<br>See:<br>TM 38-230-1 for comprehensive review.<br>MIL-C-104<br>Fed Spec NN-P-530<br>Fed Spec PPP-B-585 | a. Inexpensive<br>b. Lightweight<br>c. Acts to absorb shock<br>d. Supply abundant | a. Deteriorates unless treated<br>b. Low strength<br>c. Easily damaged<br>d. High moisture-vapor transmissibility<br>e. Subject to physical distortion — shrinking and warping<br>f. Highly combustible<br>g. Subject to attack by rodents, insects, etc. |
| Fiberboard<br>See:<br>TM 38-230-1 for comprehensive review.<br>Fed Spec PPP-B-636<br>Fed Spec PPP-B-640 | a. Inexpensive<br>b. Uniform strength characteristics<br>c. Can be treated to resist water penetration<br>d. Can be prefabricated<br>e. Can be collapsed and shipped flat<br>f. Easy to assemble<br>g. Lightweight<br>h. Provides shock protection | a. Use limited to small, relatively lightweight items<br>b. Easily damaged by penetration and structural distortion<br>c. Experiences loss of rigidity when exposed to water or prolonged moisture<br>d. Highly inflammable<br>e. Normally cannot be reused and does not permit periodic inspection of contents |

(cont'd on next page)

TABLE 8-1
CONTAINER BODY MATERIALS—SELECTION GUIDE (cont'd)

| Material | Advantages | Disadvantages |
|---|---|---|
| Plastic<br>See:<br>MIL-C-4150<br>L-P-1183 | a. Excellent moisture-vapor barrier<br>b. Can be molded to minimize assembly operations<br>c. Available in various compounds and densities to provide shock protection<br>d. Inexpensive when mass produced<br>e. Inert to climatic exposure | a. Use currently limited to small containers<br>b. Reliability of bonding technique questionable<br>c. Small lot production—uneconomical<br>d. Stress concentration at corners compromises structural integrity<br>e. Subject to distortion at high temperature |
| Honeycomb Sandwich<br>See:<br>MIL-STD-401<br>MIL-C-21275<br>MIL-C-8073 | a. Lightweight<br>b. Excellent strength characteristics<br>c. Excellent insulating characteristics | a. Expensive<br>b. Complex assembly procedure<br>c. Need for caulking and resin bonds compromises performance<br>d. May become unavailable for container use in time of emergency |

to the body only those requirements necessary to provide structural support, physical protection, and a practical handling configuration. This separation of function provides the designer with more latitude in the selection of materials and permits the use of the less expensive wood and fiberboard.

Climatic protection, including the resistance to water vapor transmission, can be provided by the use of auxiliary flexible barrier materials. The state of the art makes available an assortment of materials which function to resist the penetration of water vapor; MIL-B-131 establishes the requirements for these barrier materials and provides guidance in their application. The use of flexible barriers, when technically feasible, often will result in a less costly container which may be classed as expendable.

## 8-10 RECORD RECEPTACLES, SECURITY SEALS, AND DATA PLATES

### 8-10.1 EQUIPMENT LOGS

#### 8.10.1.1 General

The equipment log is the historical record for a specific type of equipment. It is a control device for mandatory recording of events during the life cycle of equipment—including receipt, operation, condition, maintenance accomplished, modification, and transfer. This record begins at time of delivery of the equipment by the manufacturer and is permanently identified with the item of equipment until the item is finally eliminated from the Army inventory.

The equipment log is a compilation of maintenance information on Department of the Army forms and must be controlled and safeguarded against loss or damage. The log is permanently identified with the applicable equipment by nomenclature and registration or serial number.

The most important use of the equipment log is to provide commanders with up-to-date information concerning the readiness of the item of equipment to which the log applies. The condition of equipment as recorded in an equipment log also permits selection of equipment requiring the greatest maintenance effort. Logical priorities for turn-in or elimination may thus be determined when partial replacement issues of similar new items become available.

The equipment log may be used as a control document for operational dispatch of equipment. When used for this purpose, the equipment log will be under the control of the operator or crew at all times.

The equipment log, currently in use, is a hard-covered binder, having dimensions of 10 in. x 8 in. x 2.5 in. with a transparent plastic wrap. The record binder contains DA Forms of the type and size prescribed in TM 38-750, *The Army Maintenance Management System*, for each specific piece of equipment. The

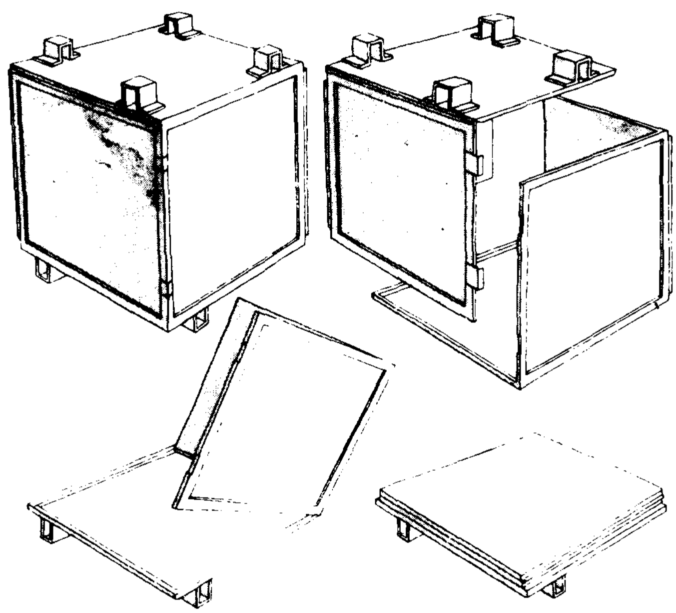


**Figure 8-18. Knockdown Container**

plastic slot located on the front of the binder is provided for identification of the piece of equipment to which the log applies. Fig. 8-19 shows the log in current use.

### 8-10.1.2 Record Receptacles

Fig. 8-20 shows the record receptacle of the SERGEANT Rocket Motor Container XM419. This receptacle is of adequate size to contain the new binder.

The record receptacles must be waterproof and must protect the contents from damage by all environments. The sealing material used must permit repeated opening and closure without impairment of the sealing qualilty. Fig. 8-21 illustrates the use of polyurethane plastic foam stripping glued to the container cover to provide a waterproof seal.

Record receptacles large enough to accommodate the current binder may either be top opening or end opening as shown in Figs. 8-21 and 8-22 respectively. The end-opening type has the advantage that it can be incorporated in the roll-over provision and therefore is easily accessible from the front of the container. This is especially desirable when the containers are stacked. The end-opening receptacle also requires less sealing material than the top-opening type. The top-opening receptacle has the advantage of hinges which affix the cover to the container body. The end-opening type requires a connecting wire for this purpose.

## 8-10.2 SECURITY SEALS

In order to discourage and detect tampering with the equipment log, the receptacle is provided with a security seal (Fig. 8-23) which must be broken in order to open the covers. Holes in the latches are for the purpose of attaching the lead seal in the manner shown in Fig. 8-24. The lead disk is then pressed closed and imprinted with the applicable agency identification. Such security seals may only be used once and must be replaced when the lead seal or wire has been broken.

Security seals also are used to seal a container by securing the seal through both the cover and body. By this means, it cannot be opened without breaking the seal.

## 8-10.3 DATA PLATES

Data plates must display only information that is necessary for the safe shipment, storage, and use of the container. The information should include the container nomenclature, Federal stock number, container serial number, part or drawing number, and the manufacturer's name. Fig. 8-25 is an example of a typical missile container data plate. These plates must be consistent in size and shape, logically oriented with respect to each other, clearly visible, placed where they will not be damaged, and horizontally labeled to read from left to right.

The material used for data plates must be compatible electrochemically, i.e., not form a galvanic cell,

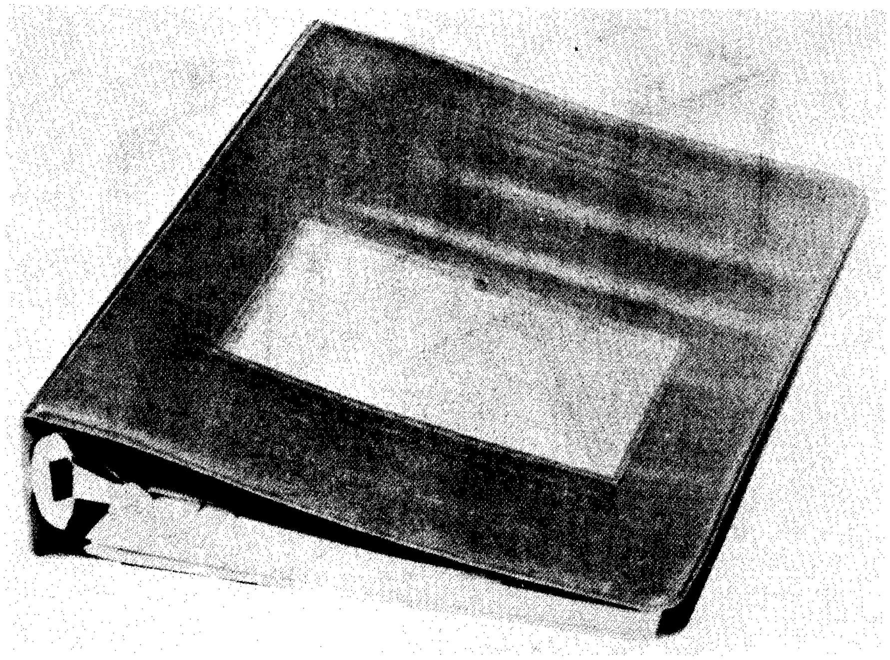


Figure 8-19. Present Equipment Log

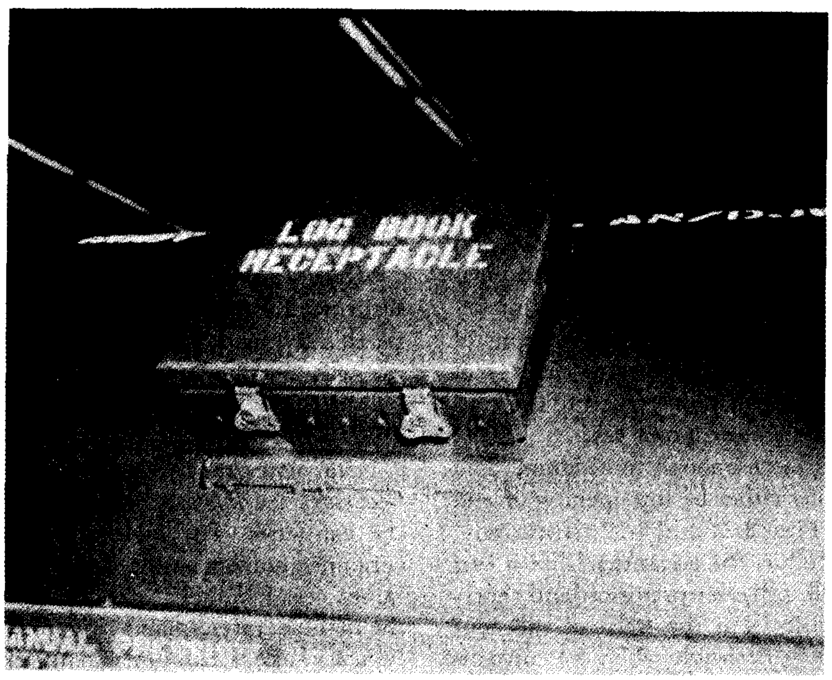



Figure 8-20. Closed Logbook Receptacle

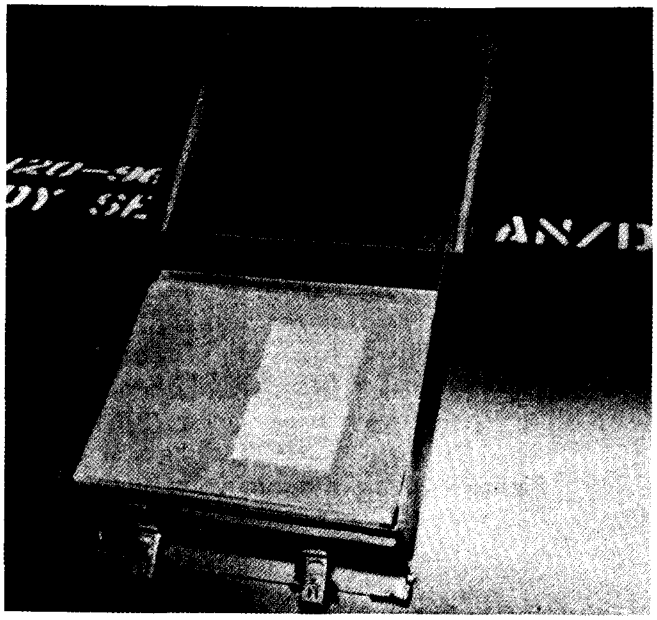


Figure 8-21. Open Logbook Receptacle

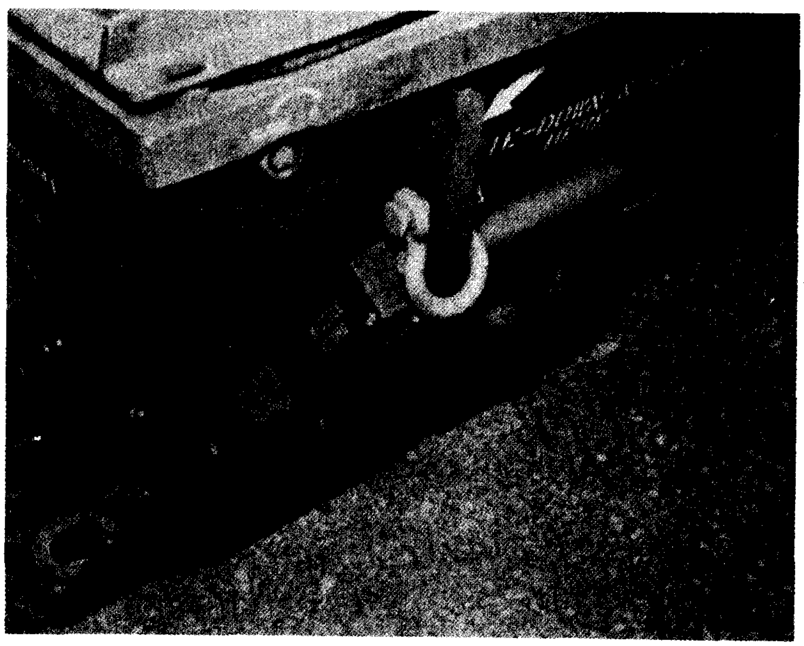


Figure 8-22. End-Opening Records Receptacle

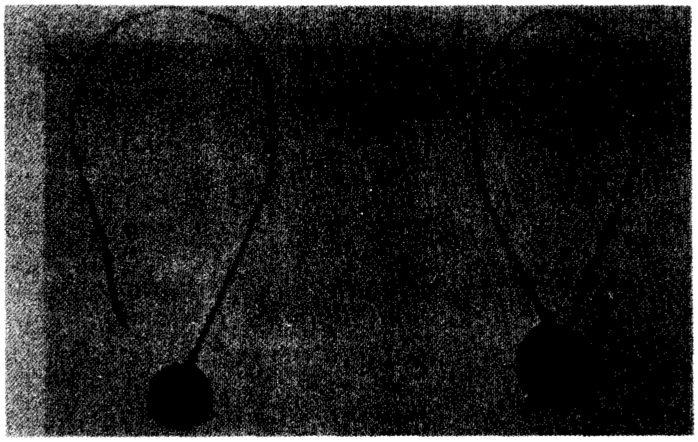


Figure 8-23. Lead Security Seals

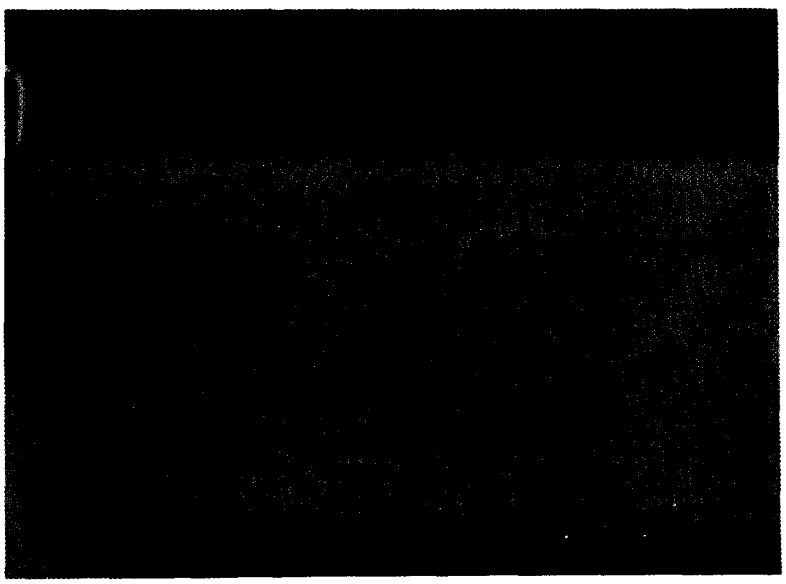


Figure 8-24. Typical Application of Security Seal

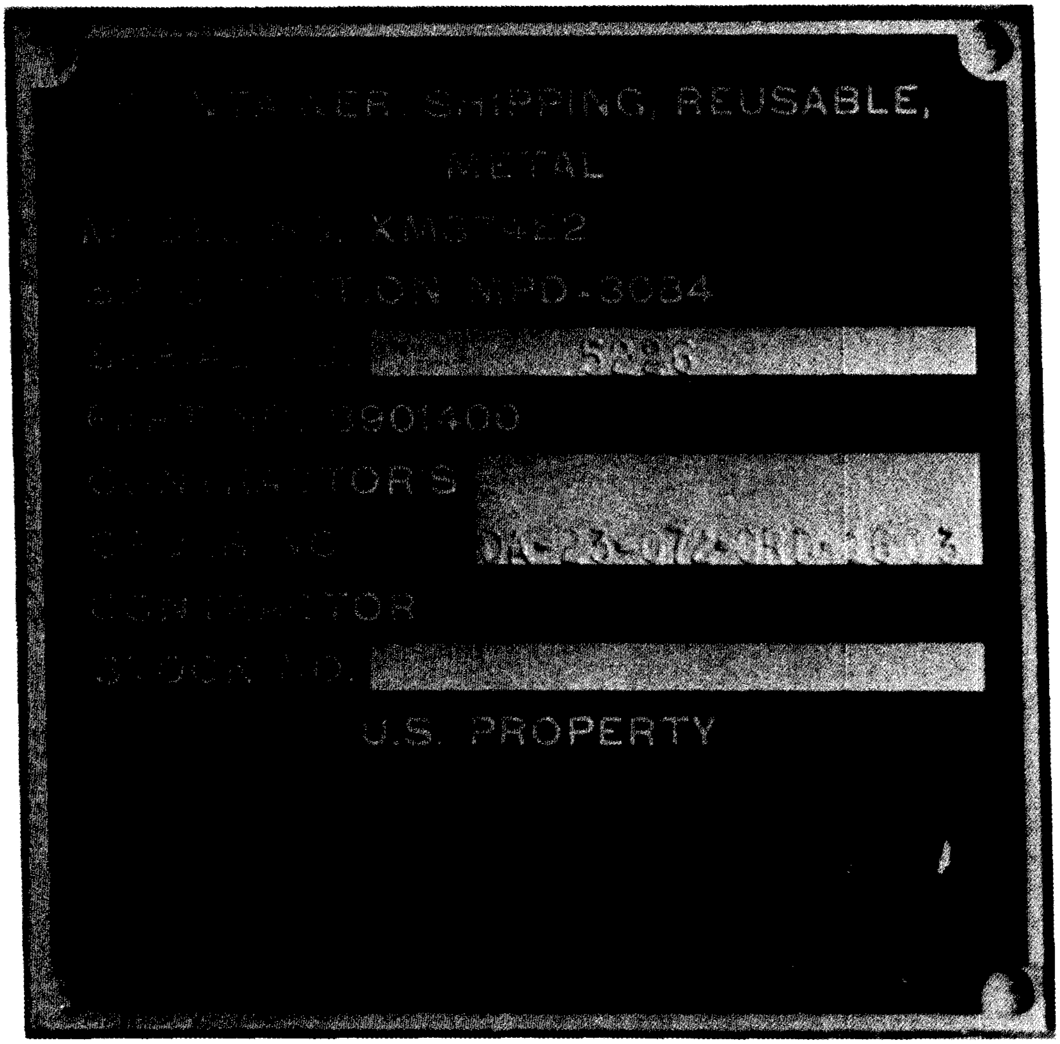



**Figure 8-25. Container Data Plate**

with the unit to which it is to be attached. The materials preferred for data plates are in the order of preference:

a. Copper-base alloys
b. Aluminum-, magnesium-, or zinc-base alloys
c. Anodized aluminum plate
d. Unalloyed or low-alloy ferrous metals.

Copper-base alloys shall conform to specification QQ-B-637. Anodized aluminum plates are plates which have been made the anode of an electrolytic cell. This oxidation of aluminum produces a surface coating which displays a relatively high resistance to corrosion and abrasion, and provides high electrical insulation to the underlying metal. Anodized aluminum plates shall be made of aluminum conforming to specification QQ-A-250/1c, 1/4 H temper.

Lettering on data plates shall be gothic or futura capitals and the numbers shall be arabic. Borders, blocks, and other characters shall be raised by etching the background to a minimal depth of 0.003 in. The plates themselves shall be 1/32 in. thick. The forming of designations such as serial numbers which vary from plate to plate usually is done by stamping.

The size of the characters for the container nomenclature or name should be at least 5/32 in. but no more than 1/4 in. in height. All other lettering and characters should be between 1/8 and 5/32 in. high with a 1/8-in. spacing between lines. Border widths shall be 3/32 in.

Container data plates shall be drilled or punched at all four corners with holes not less than 1/8 in. or more than 3/16 in. in diameter. These plates shall be fastened to the container with rivets.

The anodizing of aluminum plates shall be in accordance with MIL-STD-171, Finish No. 7.2.1. The background of data plates shall be finished in accordance with Finish Nos. 20.4, 20.8, 21.3, 21.5, or 21.11 of MIL-STD-171, Color No. 37038 (black) of FED-STD-595. Finish Nos. 20.4 and 20.8 are lusterless paint finishes. Finish Nos. 21.3, 21.5, and 21.11 are semigloss paint finishes. The unpainted portions shall be coated with clear lacquer.

# CHAPTER 9
# HANDLING DEVICES

*The design of containers to resist the additional loads imposed by handling devices and stacking, and the incorporation of features to permit stacking and withstand handling loads are presented.*

## 9-1 GENERAL

The container, in addition to being required to resist the hazards and deteriorating effects of its environment, must also provide compatibility with the handling operations necessary to move the container to its destination. The functional mobility of the container usually is dependent upon the auxiliary handling equipment operating within the logistic cycle; however, the container must include devices to result in compatibility with the handling equipment. It is the container and these handling devices which are of particular concern to the designer since it is in this area that he can make a significant contribution to the expeditious and safe delivery of materiel. Those elements of the logistic cycle whose effective performance is dependent upon the container and its handling devices are:

a. Manual handling
b. Mechanical handling
c. Unitization
d. Skids
e. Stacking provisions.

Each shall be discussed in subsequent paragraphs.

Except for special applications, the container designer has little or no control of the equipment which will be used for handling; however, he must be cognizant of and consider handling equipment when designing the container.

## 9-2 MANUAL HANDLING

The ability of a container to be manually handled is dependent upon its weight and/or size. In addition, the principles of human factors engineering dictate and establish limits which the designer cannot exceed. Fig. 9-1 and Table 9-1 define these limitations.

The chief distinguishing characteristic of containers capable of manual handling are handles whose number will be in direct proportion to the ratio of gross weight to the established man-carry limits. The state of the art makes available to the designer an unlimited selection of types and styles of handles. Those considered applicable to military container application must embody certain characteristics which are considered essential. The data contained in Table 9-2 provide guidance in the design and selection of acceptable one-hand lift bar-type handles.

In addition to the guidance given in Table 9-2, the preferred handle should encompass the following:

a. Spring loading to retract the handle to within the container profile when not in use
b. A rubber bale to provide both comfort and an effective friction grip
c. A positive stop to restrict the handle motion to 90 deg to avoid injury to operating personnel
d. Corrosion resistance
e. Unaffected by subfreezing temperatures and ice formation.

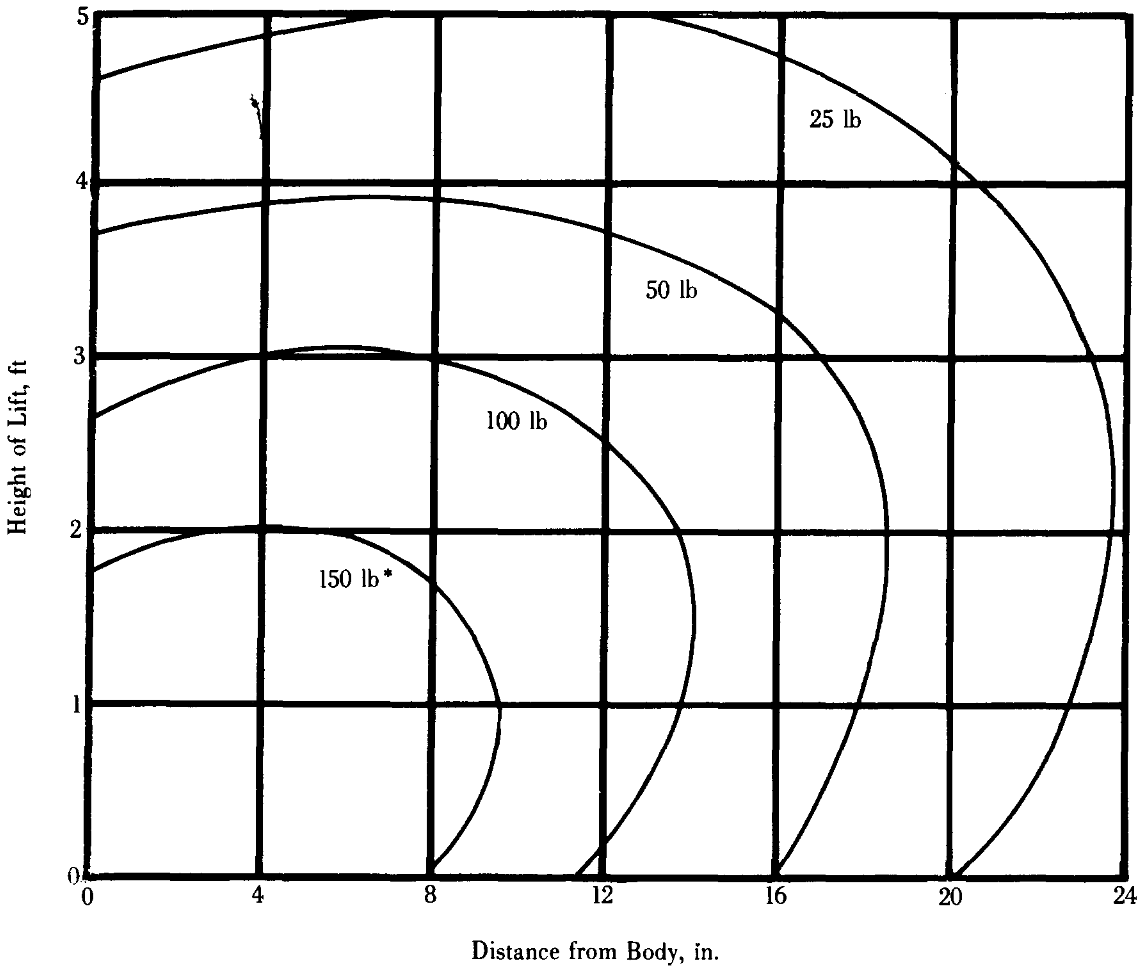
A handle embodying the preferred characteristics is depicted in Fig. 9-2 and may be procured in any of the conventional materials from numerous military and commercial supply sources. The handle illustrated should be spot welded to the container shell, provided the materials are the same and the shell can be adequately braced to withstand the stresses imposed by the load. Bolts may be used where welding is not feasible; however, a backing plate should be provided to assure adequate stress distribution. Handles should be symmetrically located above the container center of balance and conveniently positioned to provide ease of operation.

Certain container configurations will permit the use of inexpensive round-rod handles permanently positioned and fastened to the body shell; however, such handles should not protrude beyond the container profile nor degrade the stacking and/or unitizing characteristics.

Molded plastic or fibrous glass containers may incorporate within the outer shell, recesses, hand grabs, or handles to facilitate handling (see Fig. 9-7).

Wooden containers and overpacks may use simple, inexpensive rope handles to conform to par. 3.3 of MIL-B-2427.

The restrictions imposed by the demands of economic feasibility do not permit the use of body recesses to house handles; the designer should avoid this costly practice regardless of its esthetic desirability.




*Numbers on the figure refer to the area under the curve, not the curve.

**Figure 9-1. Manual Lifting Capacity: Lifting Forces That Can Be Exerted by 95% of Personnel, Using Both Hands**

Handles may perform a secondary function as tie-down receptacles provided the forces imposed are within the load-carrying capability of the handles.

## 9-3 MECHANICAL HANDLING

Within the environment of worldwide distribution may be found a wide assortment of material handling equipment ranging from the simple block and tackle to elaborate automated conveyor systems. Falling within these extremes are the more common forklift truck, overhead crane, and hand truck. The effectiveness of this equipment is dependent upon the container and the handling devices it encompasses to facilitate the handling process. The containers and their fittings may be divided into four general and occasionally overlapping categories:

a. Hoisting fittings
b. Tie-down fittings
c. Towing fittings
d. Forklift provisions.

Each category is discussed.

### 9-3.1 HOISTING FITTINGS

Overhead cranes—whether they are stationary or mobile—employ hooks, slings, and/or yokes to engage and support the suspended container. Obviously, the container must incorporate or be provided with devices to accept and be compatible with these handling methods.

Handling devices—either integral or attached to the container which will provide the required compatibility—may take the form of eyes, rings, or lugs. They may be located anywhere on the container; however, it is preferable that they be positioned above the center of gravity of the supported item to assure load stability during the lifting operation.

**TABLE 9-1. MAXIMUM WEIGHT LIMITS**

| Type of Handling | Height Lifted, ft | | | | | |
|---|---|---|---|---|---|---|
| | 1 | | 2 | 3 | 4 | 5 |
| Lifting[1,3], lb: | | | | | | |
| One man | 85 | | 80 | 65 | 50 | 35 |
| Two men | 170 | | 160 | 130 | 100 | 70 |
| Carrying[2] (five steps or less), lb: | | | | | | |
| One man | | 65 | | | | |
| Two men | | 130 | | | | |

[1]These weight limits should be used as maximum values in establishing the weights of items that must be lifted. These limits apply to items up to 15 in. long and up to 12 in. high, with handles or grasp areas as shown in Table 9-2. These limits should not be used for larger items, or for items which must be lifted repetitively.

[2]These weight limits should not be used if personnel must carry the item more than five steps.

[3]When an item weighs more than the limit for one-man lifting, it should be prominently labelled with weight and lift limitations, (e.g., two-man or mechanical lift). Items to be lifted mechanically should have prominently labelled hoist and lift points.

**TABLE 9-2**
**DESIGN AND SELECTION OF ONE-HAND LIFT BAR-TYPE HANDLES**

| Weight to be Lifted $W$, lb | Handle Diameter, Minimum, in. | Handle Width, in. | Finger Clearance, in. |
|---|---|---|---|
| $15 < W$ | 0.25 | 4.5 | 2.0 |
| $15 \leq W < 20$ | 0.25 | 4.5 | 2.0 |
| $20 \leq W < 40$ | 0.75 | 4.5 | 2.0 |
| $W \geq 40$ | 1.00 | 4.5 | 2.0 |
| with gloved hand | — | 5.25 | 3.5 |
| with mittens | — | 5.25 | 3.5 |

Hoist fittings attached to large, top-opening, sealed containers should be located on the bottom half of the container to avoid subjecting the cover latches to the full weight of the suspended mass and degrading the effectiveness of the barrier seal. Hoisting fittings may serve a dual purpose by functioning as stacking pads and/or tie-downs.

Some applications may warrant special cable slings permanently attached to the container. This is typical of missiles whose attitude is considered critical, and proper container orientation is mandatory.

Small containers, with or without handles, normally will not require hoist fittings. Containers whose gross weight exceeds 150 lb shall be equipped with lifting rings or eyes whose clear inside diameter shall be at least 2.5 in. (preferably 3.5 in.). These fittings shall not protrude beyond the container envelope when not in use nor shall they degrade the cubing capability of the container configuration. A design factor of safety of no less than 4 to 1 shall be applied to hoist fittings. Should the function of the hoist fitting be limited merely to the removal of the container cover, it should be clearly marked as to its limitations. However, it is preferable that the hoist fittings be capable of supporting the total weight since they will undoubtedly be exposed to misuse at some time within the operating environment.

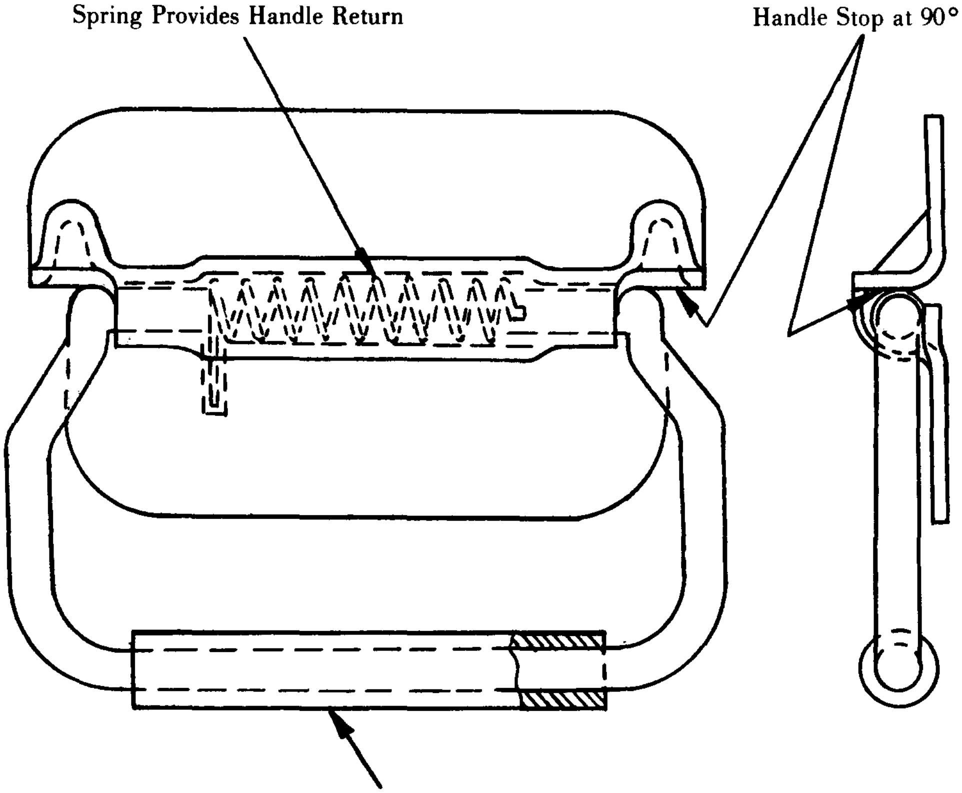



**Figure 9-2. Handle Embodying Preferred Characteristics**

### 9-3.2 TIE-DOWN FITTINGS

The requirements for tie-down fittings are fully documented in the Bureau of Naval Weapons publication WR-11. Par. 6.5 of Part I is quoted in toto to provide the required guidance:

"1. Tie-down fittings shall be provided on all containers grossing 1,000 lb or more. Such fittings may include the hoisting fittings.

"2. The design load in any direction below the plane of the fitting must be at least 1.5 times the maximum load of the fitting based on the yield strength.

"3. Whenever possible, place fittings at least 18 in. above the baseline and above the plane of the center of gravity of the loaded container. Space fittings along each side, equidistantly from each other and symmetrically above the center of gravity.

"4. The actual number required shall be the theoretical number, except that at least 3 fittings shall be provided on each side of a container more than 10 ft long and at least 2 on each side of a container less than 10 ft long. When a container is more than 75 in. wide, furnish at least one fitting on each end.

"5. A clear inside diameter of 2.5 in. is required."

### 9-3.3 TOWING FITTINGS

Medium to large containers shall be equipped with two tow eyes at each end. They shall be positioned as close to the ground as possible and suitably supported by a structural member capable of withstanding the drawbar pull developed by the towing action. These fittings shall include a ring or an eye having a minimum diameter of 2 in., and their design shall include a safety factor of at least 4. Strategically located hoist fittings may preclude the need for tow fittings and, conversely, the tow fittings may negate the need for hoist fittings. Fig. 9-3 illustrates a tow fitting.

### 9-3.4 FORKLIFT PROVISIONS

The versatility and wide acceptance of the forklift truck since World War II has assigned to this handling mechanism a unique position of general application; it will be found in all transit and storage environments (see Fig. 9-4). Consequently, one may assume that virtually all containers will at some time be handled by a forklift truck. To provide the required handling compatibility, the container should incorporate provisions to accept the tines of the fork-

**Figure 9-3. Tow Fitting**

lift truck. This requirement is applicable to all containers whose gross weight exceeds 300 lb; containers weighing less than 300 lb may or may not incorporate handling devices to facilitate tine positioning. The decision is left to the container designer and is dependent upon the anticipated handling methods of the proposed application. Quite often small containers are unitized (see par. 9-4) and positioned on skids or pallets to provide handling compatibility.

To permit for general application, forklift trucks have been standardized according to their lifting capacity, height of lift, degree of mobility, and fork configuration. Of these characteristics, only the tine size and fork spread affect the dimensions of the container. Table 9-3 provides forklift data to assist the container designer in providing handling compatibility.

The characteristics of a typical container designed to be compatible with forklift truck handling methods are:

a. Underclearance or apertures (tine openings) should be provided at both ends and on each side. Since end handling accounts for one-third of all material transfer operations, end openings are necessary to permit movement through narrow doors and aisles.

b. The spread of the fork apertures should be designed to accommodate all forklift trucks that have the capacity to handle the container. In order to assure maximum load stability, the maximum lateral fork spread possible should be used, i.e., for a 5000-lb container a fork spread of 34 in. outside to outside should be used.

c. The amount of underclearance or depth of tine aperture should be capable of accepting any or all of the conventional truck forks including rough terrain models.

d. The container center of gravity should, if possible, fall within the load center limits of the fork length as limited by the truck configuration and capacity.

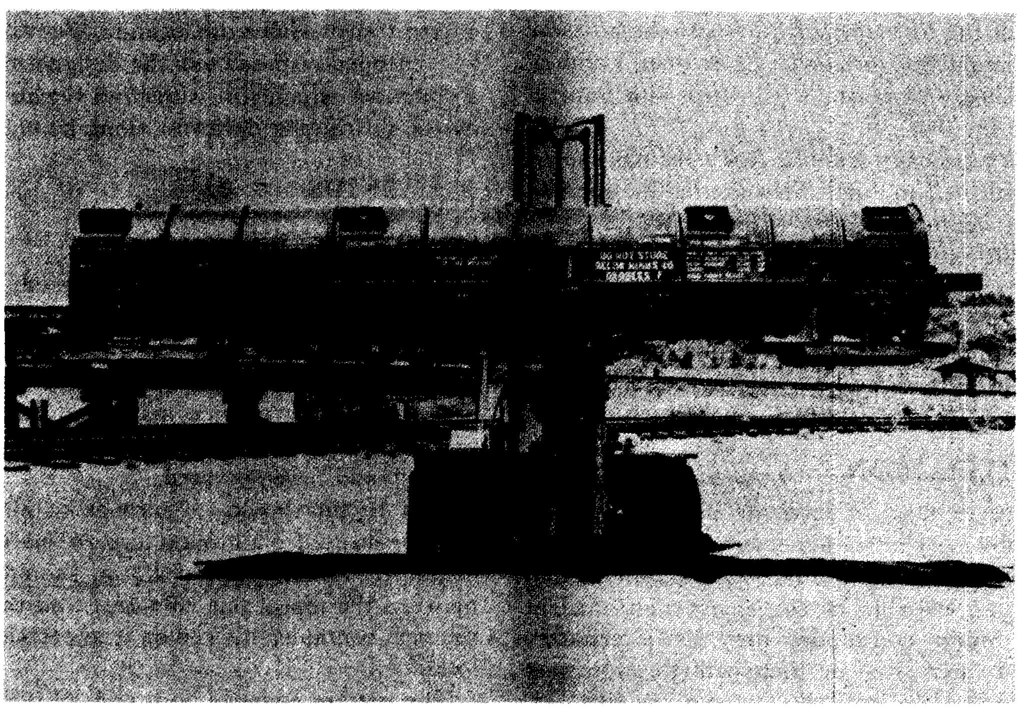


**Figure 9-4. Forklift Lifting a Container**

**TABLE 9-3**
**FORKLIFT DATA**

| Nominal Capacity*, lb | Fork Thickness At Heel**, in. | Fork Width, in. | Fork Length Max, in. | Fork Together Max†, in. | Fork Spread Min†, in. |
|---|---|---|---|---|---|
| 2,000 | 1.5 | 4 | 36 | 12 | 28 |
| 4,000 | 1.75 | 5 | 40 | 12 | 32 |
| 6,000 | 2 | 6 | 40 | 15 | 34 |
| 10,000 | 2.5 | 7 | 48 | 18 | 52 |
| 15,000 | 2.5 | 8 | 48 | 18 | 58 |

*Measured with load center 24 in. from heel. On loads more than 4 ft wide, capacity is reduced by taking the moments from fulcrum, i.e., the front axle.
**0.5 in. for all at the tip.
†Outside to outside.

e. Tine openings should be symmetrically located about the center of balance of the loaded container.

f. The container body should be reinforced or protected in those areas which will make contact with or be exposed to the forks. Fig. 9-5 is an example of a container that was not protected in the area of the end forklift openings. Notice the dents in the bottom of the container.

g. Push or bumper plates should reinforce the periphery of the fork aperture to resist the pressure exerted by impacting fork ends. Quite often, containers are pushed and must be provided with bumper plates (see Fig. 9-6).

h. When physically feasible, fork openings should be 12 in. wide × 3 in. high. This size forklift opening will accommodate most sizes of forklift trucks.

i. Forklift provisions should be fastened to the container in a manner that does not impose any load directly on the shell. These provisions should be attached to reinforcing members which absorb the load or distribute it more evenly over the surface of the shell.

## 9-4 UNITIZATION

Loads are unitized to facilitate handling and to provide stability. Unitization refers to stacking patterns and/or devices used to interlock containers into one solid unit capable of convenient and efficient handling. Small containers may be alternately stacked and interwoven or their configuration may provide interlocking capability by nesting (see Fig. 9-7). Quite often the unitized load is placed on a skid or pallet and is strapped to these handling devices.

Large containers may often be equipped with tie bars to connect one to the other to result in a self-supporting rigid structure. These tie bars must be designed to resist the dynamic effects of the transit environment (see Fig. 9-8).

There are various techniques applicable to the interlocking process (see Fig. 9-9). However, regardless of whether the load is unitized or not, some form of strapping or tie-down is used to restrain the load during transit. Since the location of strapping cannot be controlled or predicted, the designer must provide a container which will withstand the stress imposed by the restraining device(s) along its entire length.

## 9-5 SKIDS

### 9-5.1 CONSTRUCTION

Any container that must be pushed, dragged, or handled by mechanical equipment should be provided with wooden skids. The skids should be positioned longitudinally at or near the extreme width of the container to provide maximum lateral stability and maximum width for forklift and entry. Lateral skids should never be used.

Skid height should be such as to allow about a 3-in. clearance from ground level to the bottom of the container. A minimum of 2.5 in. should be allowed between the top of one container and the bottom of the next container stacked on it to permit removal by forklift.

The bottom edges of both ends of skids should be chamfered to reduce the tendency to catch on irregularities of the floor or ground, and to reduce splitting

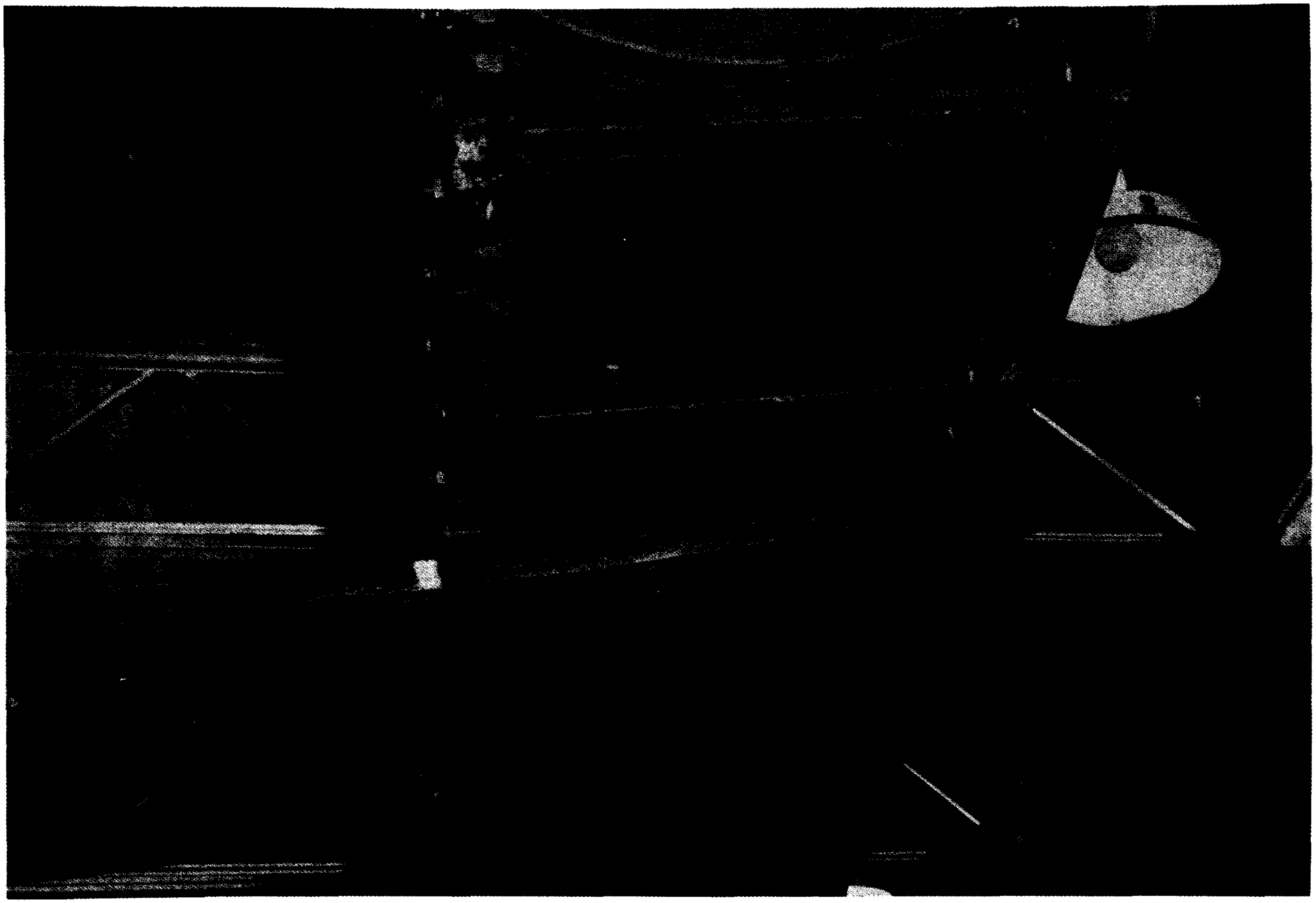


Figure 9-5. Container Insufficiently Protected for End Forklift Handling

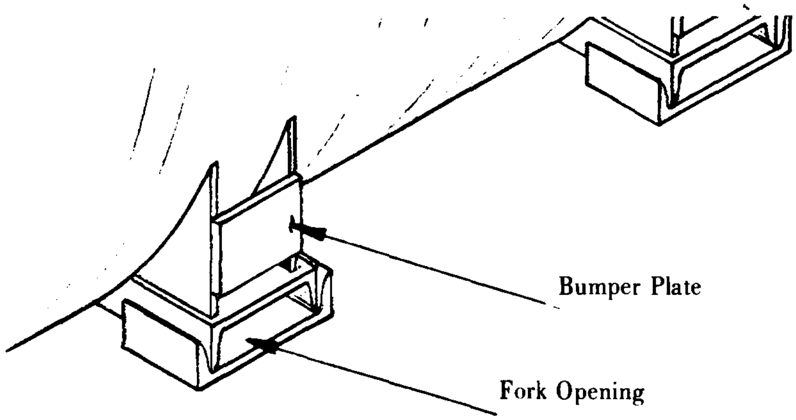



**Figure 9-6. Fork Openings and Bumper Plates**

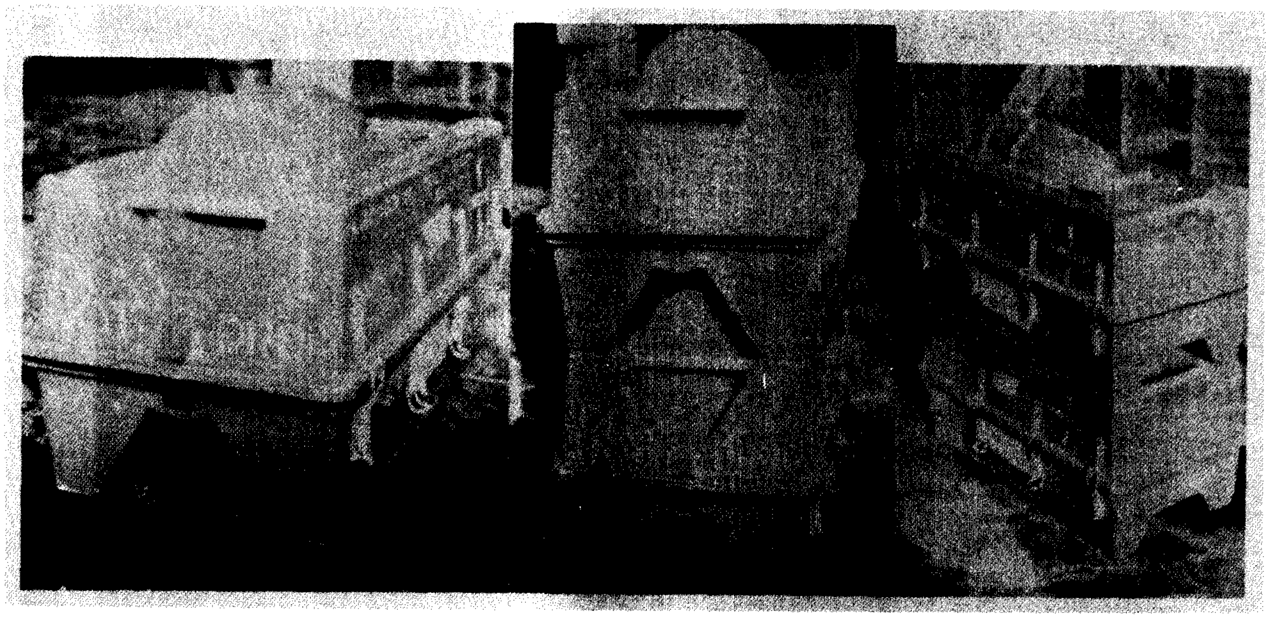


**Figure 9-7. Stacking and Nesting**

of skids. The chamfers should not be more than 0.75 in. high by 1 in. long (Fig. 9-10(B)). Chamfers that are too large hinder effective end blocking in transportation (Fig. 9-10(A)). The blocking contacts the skids so high that it cannot adequately resist impact loads, and tends to tear loose from the floor of the carrier. The ends of the skids should also project at least 2 in. beyond the extreme end of the container.

The inner ends of wooden skids should be backed up by stops, integral with the structural members of the container, and of sufficient strength and rigidity to prevent longitudinal shifting of the skids under rail impact loads (Fig. 9-11(A)). Maximum impact velocity in rail impact tests is 10 mph. When a rail car loaded with containers is rolled into a string of stationary cars (humped), the containers tend to continue forward, but the skids are restrained by blocking. If the skids are attached to the container only by bolts, without the use of stops, relative movement between the container and skids may occur, causing the wood to split through the bolt holes.

The skids also should be notched on the bottom with the notch being the same width as the stacking pad and 0.5 to 1 in. deep. The notched skids will prevent any longitudinal movement of stacked containers while the stacking pad design will prevent any transverse movement of stacked containers (Fig. 9-11(B)).

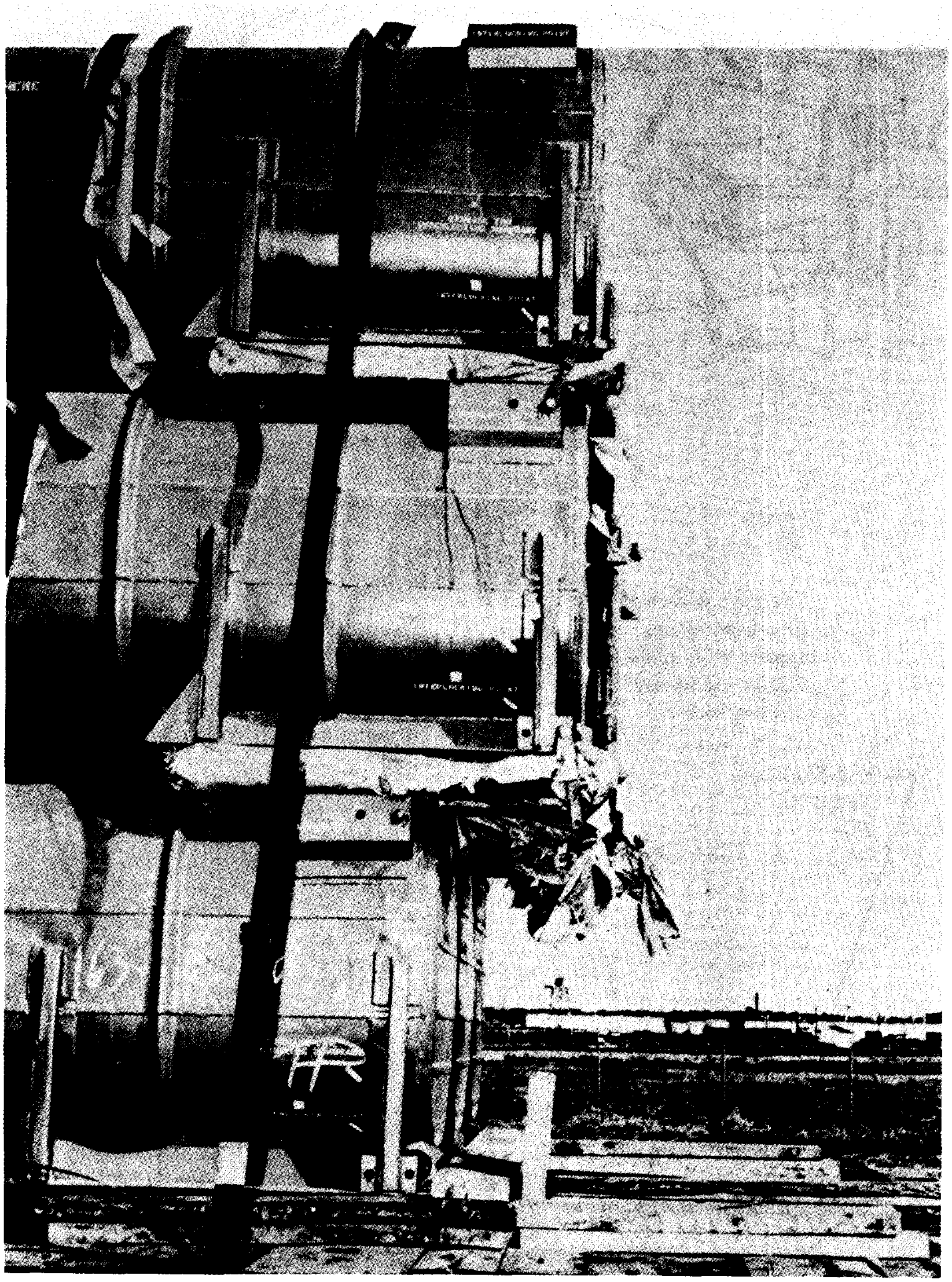


Figure 9-8. Tie-Bar Failure

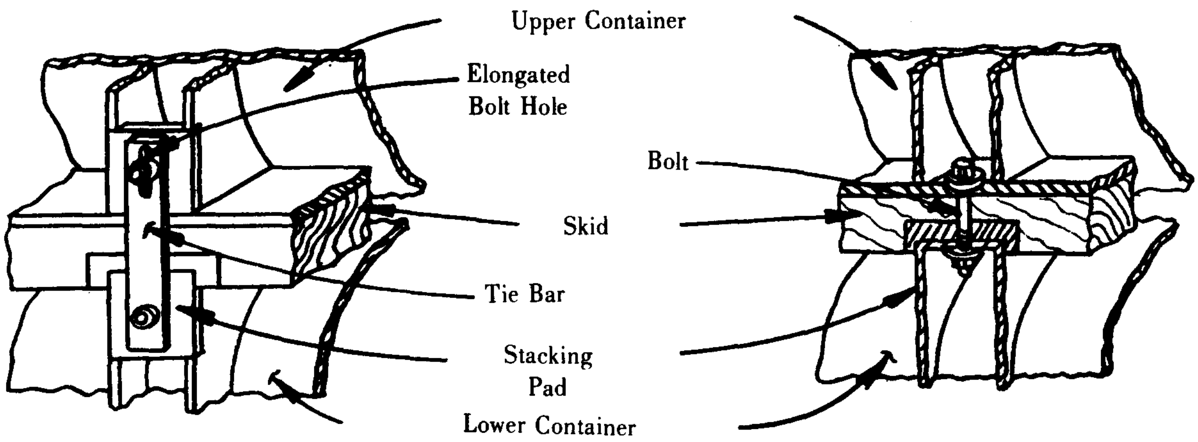



**Figure 9-9. Unitizing Devices**

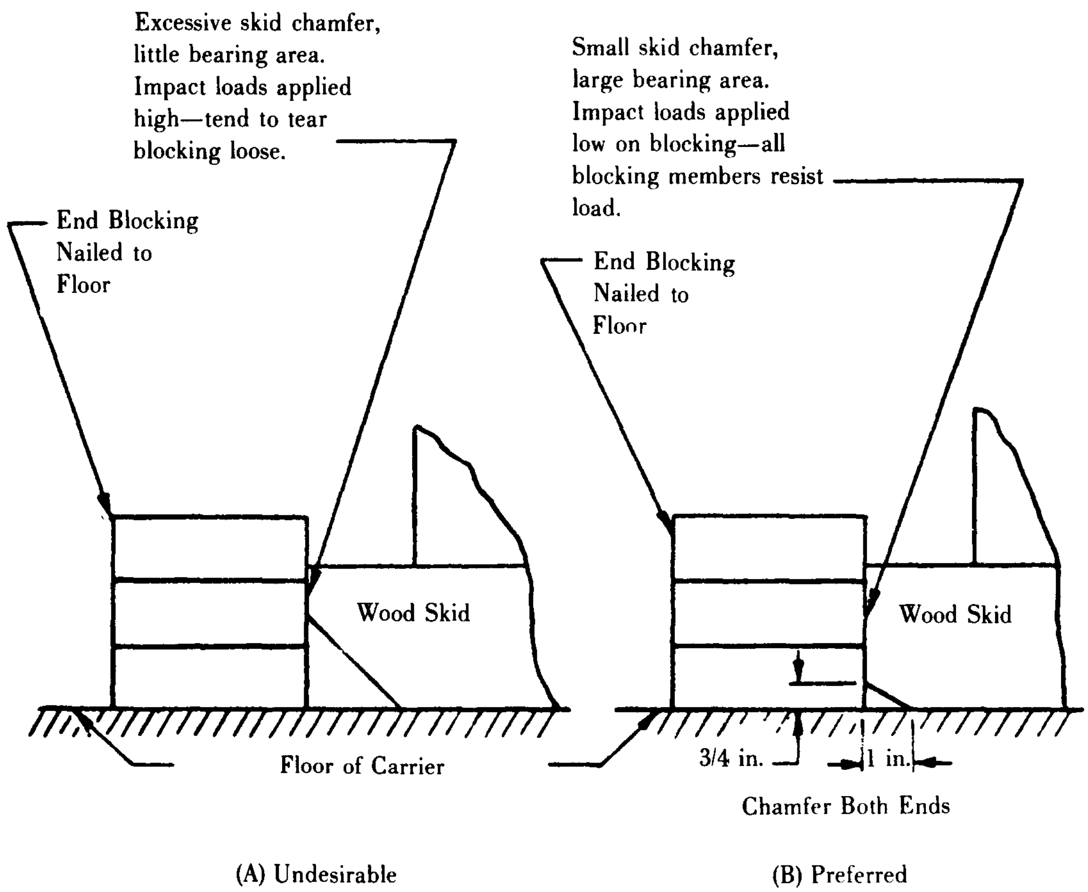



**Figure 9-10. Skid Chamfers**

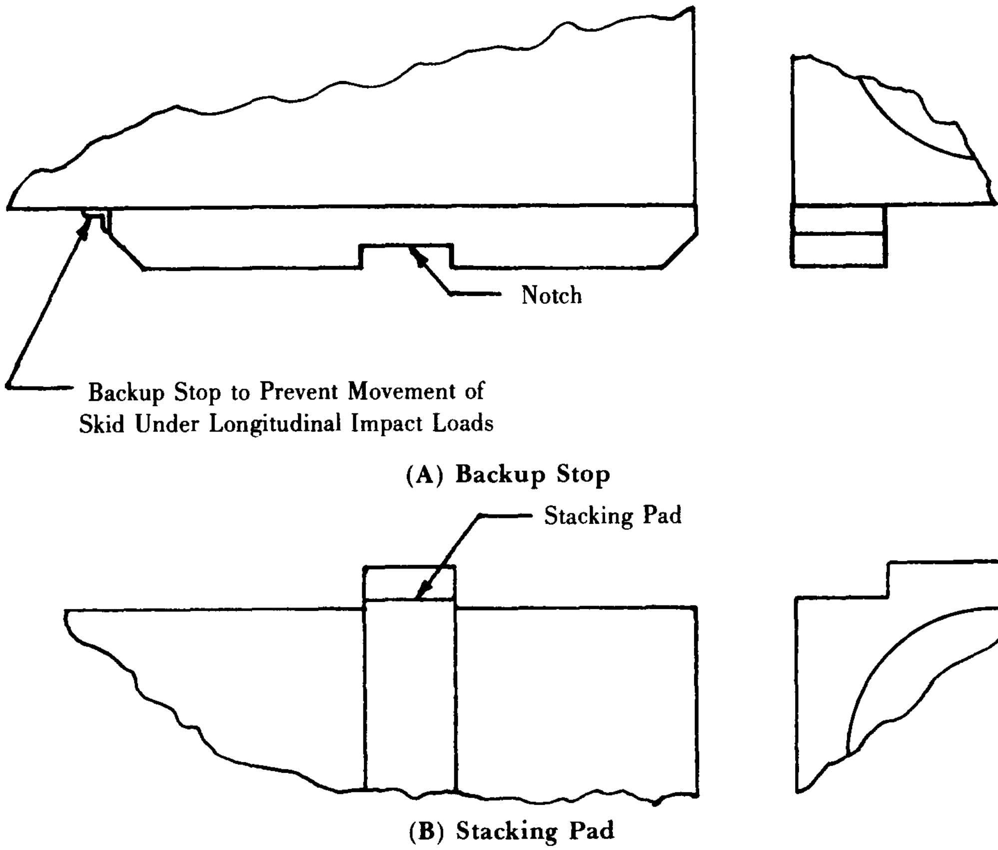
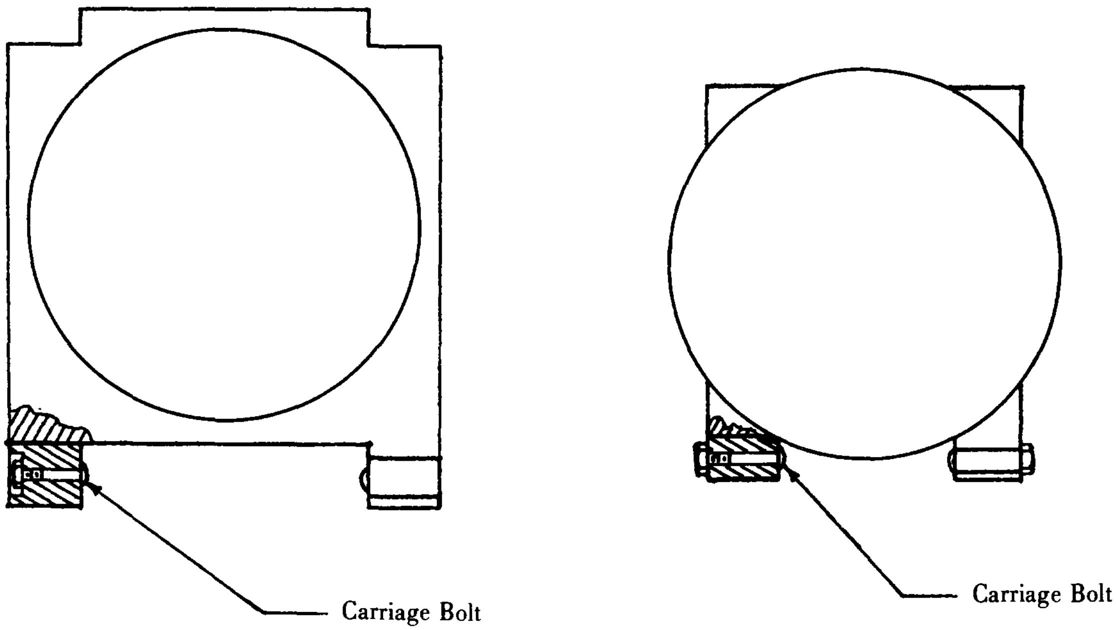



**Figure 9-11. Interlocking Skid**

Additional precautions should be taken to reduce the possibility of longitudinal splitting, and to prevent the skids from breaking apart if they do split. The most common method of preventing splitting of wooden skids is by installing carriage bolts transversely through the skids 2 or 3 in. from each end. Washers should be used under the nuts. These carriage bolts should be positioned as shown in Fig. 9-12. When the nut and end of the bolt protrude outside of the extremeties of the container, the bolt hole should be countersunk on the outside of the skid to recess the nut and end of the bolt within the perimeter of the container. The carriage bolt should be positioned so that the head is always on the inside of the skid.

The incorporation of cushioning, springs, or other shock mitigation features in skids or between the skids and container structure should be avoided. Containers having such skids cannot be unitized effectively or tied down for shipment unless dunnage is used under the structural members of the container to raise the skids off the vehicle floor and provide solid bearing. The skids then are no longer effective in isolating the container and contents from transportation shocks and vibrations. If the containers are not blocked, flexible shock mitigation arrangements allow the containers to bounce as the springs or cushioning alternately compress and recover. During the compression phase of the cycle, slack develops in the shipping bands; during recovery, the upward motion of the containers imposes excessive forces on the shipping bands. The condition is amplified when the containers are stacked one on another. If rigid, crushable cushioning is used, and the containers are supported on the skids during shipment, the cushioning will crush as soon as the design load is exceeded. These materials provide little or no shock mitigation after they crush because they do not recover. It may also happen that the material will not crush simultaneously at all four skids. In that case, the load will become more unstable. Fig. 9-13 shows a cushioned skid that has been damaged by rough handling.

The bearing areas of skids must be adequate to support the weight of the container without causing excessive stresses in the skids and without exceeding floor loading limitations. Normally, the most critical floor loading limitations will be those established for aircraft. The designer should provide enough bearing




(A) Nut Countersunk to Keep Bolt Within Confines of Container Perimeter

(B) Countersinking Not Required

**Figure 9-12. Location of Carriage Bolts**

area to stay within the limitations imposed by any aircraft in which the missile is expected to be transported.

## 9-5.2 PRESERVATION

Wooden skids shall be made of hardwood in accordance with Specification MM-L-736, *Lumber and Timber: Hardwood, Number 2 Common, Unplaned and Air-Seasoned*.

Under no conditions should green lumber be used for the fabrication of skids. Green lumber is lumber that has been freshly sawn and has received no intentional drying; for oak it may have a moisture content ranging from 64 to 83%. Lumber with this moisture content would require a considerable period of time to dry to 18% moisture content if it were continuously stored outdoors. The shrinkage and distortion of wood due to its drying only occurs when the wood is dried to a moisture content below the fiber-saturation point. The fiber-saturation point for all species of wood occurs at approximately 30% moisture content. Green lumber may therefore be dried to approximately the fiber-saturation point without any apparent shrinkage, checking, or distortion. Further drying below the fiber-saturation point may easily cause these defects. Therefore if the skid is fabricated when the moisture content is at or above the fiber-saturation point, subsequent drying of the skid could result in distortion of the skid. In order to help eliminate this condition, the establishment of moisture content limits at the time of acceptance, and a further check at the time of fabrication, should be incorporated. These limits should be set at 18% maximum at the time of acceptance and should be noted as a requirement on the skid drawing. Eighteen percent should also be specified as the maximum moisture content permitted at the time of fabrication. Fig. 9-14 shows a skid that was fabricated from wood with an excessive moisture content and was subsequently dried to a lower moisture content after fabrication.

Wooden skids shall be preserved by pressure treatment in accordance with Specification TT-W-571, using pentachlorophenol equivalent to 5% (Specification TT-W-570, in petroleum oils conforming to AWPA Standard P9). A minimum net retention of 10 $lb/ft^3$ or refusal, whichever is less, should be specified. This method of preservation is used for lumber products in contact with the ground or water and is suitable for the treatment of products that do not require painting.

Some skids have previously been preserved in accordance with finish number 25-1 of MIL-STD-171. This treatment is used when painting of the skids is required. This method of preservation for skids is not recommended however, since the skids will be in contact with the ground and water. It is also doubtful as

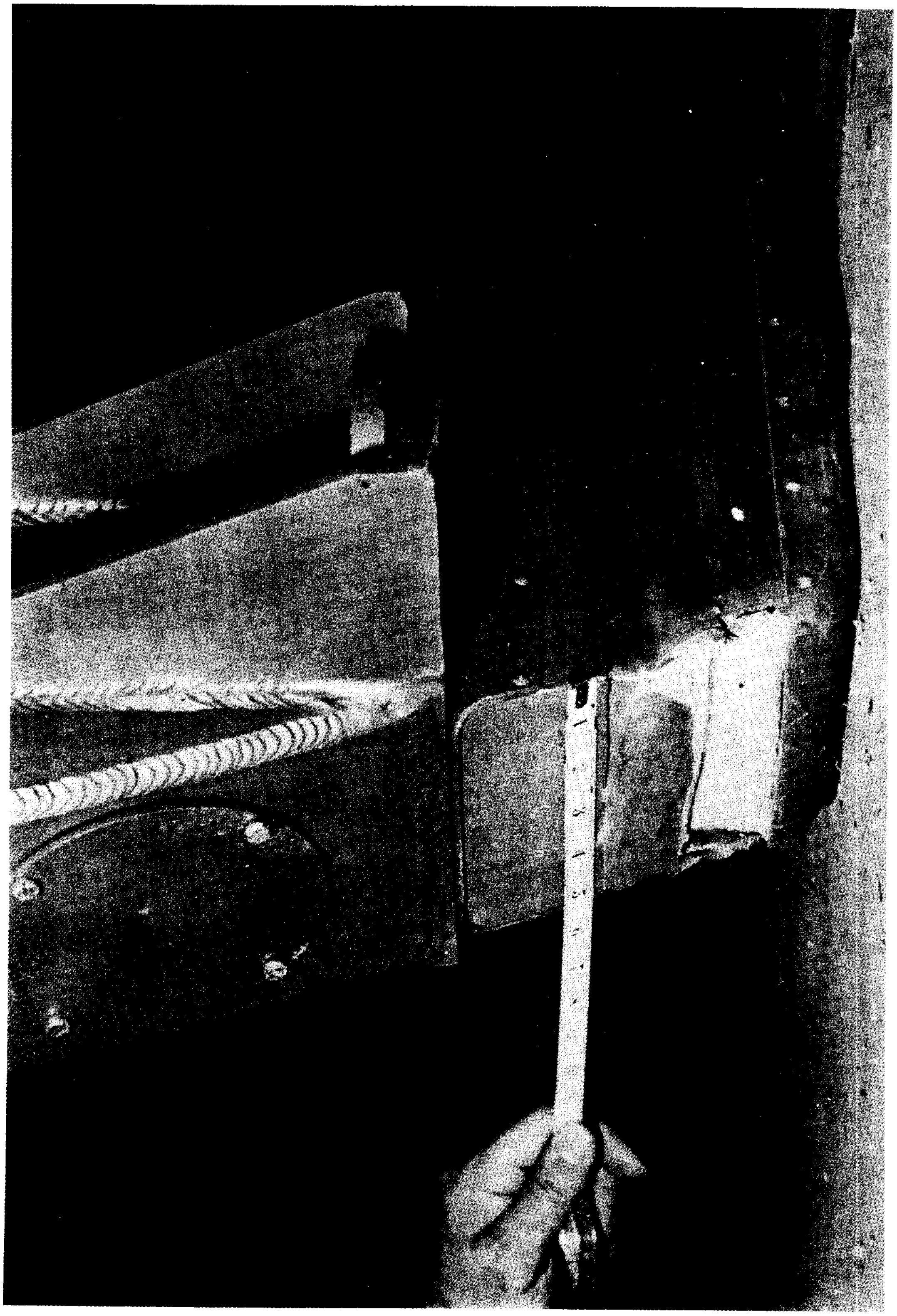
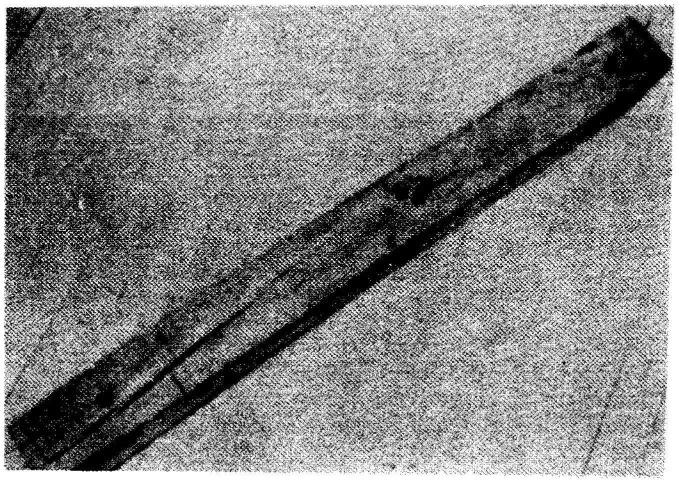
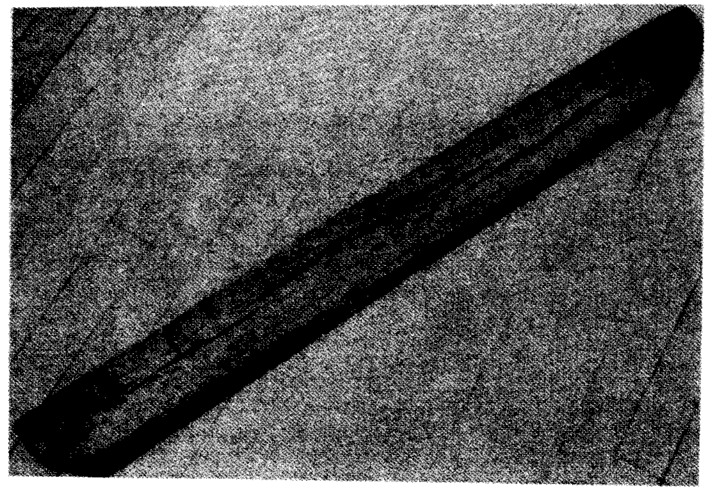


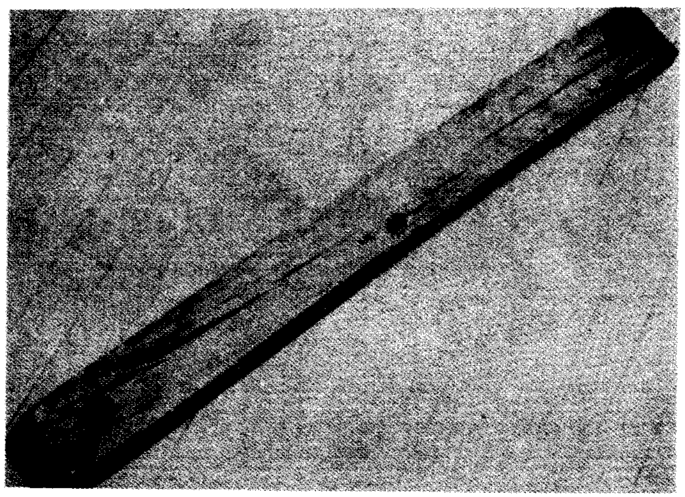
Figure 9-13. Damaged Cushioned Skid



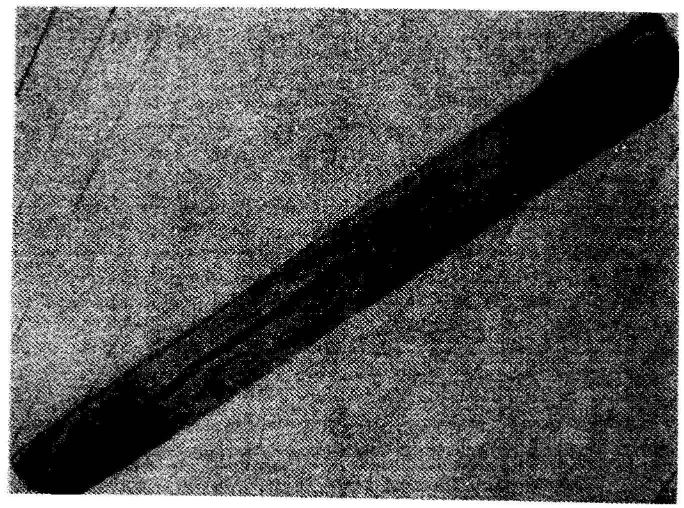
(A) Top View



(B) Left Side View



(C) Bottom View



(D) Right Side View

**Figure 9-14. Skid With Excessive Warpage, Cracking, and Shrinkage**

to what value painting adds to the skid. The disadvantages of painting are the increased cost and the bleeding of the preservative through the paint.

Creosote also has been used as a preservative on skids. The main disadvantages of this preservative are the objectionable odor, bleeding, and tar deposits. When the container is pushed or pulled during handling, transportation, and storage, a tar skid trail often is left behind.

Water-borne preservatives are another common type of preservative used for the preservation of wooden skids. The main disadvantage of water-borne preservatives is that they do not offer adequate protection to the item since leaching results when the skid is exposed to water or ground areas of moderate or high rainfall. Wood impregnated with this preservative swells upon treatment, requires redrying for most purposes, and shrinks upon drying.

Pressure treating with water-borne preservatives could also possibly contribute to distortion of wooden skids. This type of treatment could raise the moisture content of the skid to such a degree that uncontrolled drying could result in checking, warping, and distortion.

Wooden skids should be cut to the final required dimensions before being subjected to a preservation treatment.

Skids with boxed heart should be eliminated. Boxed heart is the term used when the pith (the small softcore found in the structural center of the log) is located entirely within the four faces of a piece of wood. This condition is known to aggravate many of the defects associated with drying. The skid shown in Fig. 9-14 is a good example of a skid that contains the pith of a tree.

Wooden skids may be laminated (Fig. 9-15) as an alternate construction method. The laminations should be constructed of Group IV woods (see Table 9-4) with each lamination being from 3/4 to 1-5/8 in. thick. The bonding adhesive should be per MMM-A-181. When nails are to be used for pressure during cementing, they should be located approximately 0.5 in. from the bottom of the skid. Transverse carriage bolts, assembled according to Fig. 9-12, should be used to prevent delamination.

## 9-6 STACKING PROVISIONS

Stacking is the placing of material in a self-supporting pile that assures stability and facilitates removal. The economic aspects of efficient space utilization have imposed upon the container the requirements that it resist the effects of stacking. Stacked in tiers, the container must:

a. Retain its integrity when subject to both the static and dynamic loads imposed upon its structure

b. Contribute and provide support to the overall stability of the stacked configuration.

The physical integrity of a container is the result of its structural design and the material used in construction. In order to retain the integrity of a con-

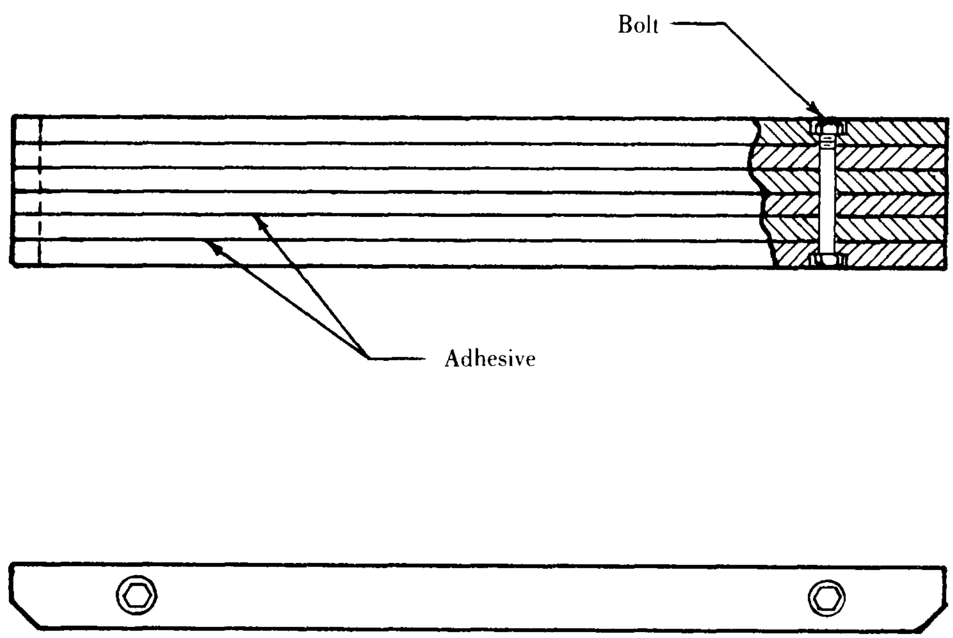



Figure 9-15. Laminated Skid

tainer while stacked, it should be provided with a load-bearing structure capable of supporting an established weight. The container top and the stacking pad must not be deformed when one container supports another, and the container should be designed so that it can be stacked in a manner not to interfere with the forklift access. For small containers, the body may be required to resist the loads imposed by stacking. Ribs or corrugations may be pressed or molded into the body of a small container to provide the required rigidity.

**TABLE 9-4. GROUP IV WOODS**

| | |
|---|---|
| Ash | Hickory |
| Beech | Locust |
| Birch | Maple, hard |
| Elm, hard | Oak |
| Hackberry | Pecan |

Stacking brackets that are welded onto the container must be structurally strong and must also provide enough area for a strong weld. Two of the weaker designs are shown in Fig. 9-16 and should be avoided in container design. These designs, in order to withstand the required loads, must have gusset plates welded inside their configuration or be made of heavy gage material. This method defeats the objective of maintaining a minimum weight. A better method is to design the structural integrity into the bracket itself. Two acceptable designs are shown in Fig. 9-17.

Large containers may incorporate structural members enveloping and supporting the relatively less rugged body shell. With the stacking pads welded to the container shell directly over the structural members, the necessary rigidity required for stacking is provided (Fig. 9-18). The structural members function as a truss, and the shell of the container is theoretically free of any externally imposed forces and merely functions to envelop its contents. With stacking pads integral to the structural truss, proper alignment of the load-bearing truss and unitization of the stack are facilitated. Such alignment allows the forces, imposed on the container by stacking, to be transmitted by the structural members, acting as columns, to successive tiers in order to relieve the container shell of the need to provide the required support. Figs. 9-19 and 9-20 illustrate some of the various stacking pad designs that have been used on missile containers. The designs shown in Fig. 9-19 incorporate a lateral stop while those shown in Fig. 9-20 do not provide lateral stops and are, therefore, inadequately designed. Fig. 9-21 shows damage caused when structural members are not used in the container shell. Fig. 9-22 shows the damage caused when inadequate structural members are incorporated in the container.

Stacking patterns and procedures are based upon the gross weight of the container and/or the limitations of available space. In addition, the transit environment will introduce dynamic loads which will limit the stack to a height less than that permissible in a passive storage environment. Stacking procedures and technique must consider both situations, and design for the condition which is prevalent and/or most severe. Table 9-5 provides guidance to the container designer and is representative of those conditions which exist in today's environment of worldwide distribution.

To achieve stability in stacking operations, wide skid spacing with allowances for the addition of roll rings is desired. Roll rings are introduced to enable a single container to roll or tip without imposing excessive lateral shock on the item. Roll rings are especially recommended for the bottom half of the container and, where it is structurally and economically feasible, are recommended for the top half of the container. This configuration is shown in Fig. 9-23.

Provisions should be made for interlocking stacked containers to provide stability and prevent shifting while in transit. Proper skid and stacking pad design will reduce the likelihood of accidental tipping or shifting while in storage or transit. The stacking pad should prevent the skid of the container from moving in both the lateral and longitudinal directions and provide stability when subjected to both static and dynamic loads. Two possible stacking pad-skid configurations are shown in Fig. 9-24.

Fig. 9-25 illustrates stacking pad provisions incorporated in the design of small containers.

**TABLE 9-5**
**STACKING LIMITATIONS**

| Container Gross Weight $W$, lb | Normal Stack Height |
|---|---|
| $W > 5000$ | Generally not stacked because of size and weight |
| $2500 < W \leq 5000$ | 2 High |
| $W \leq 2500$ | 3 High or to a height of 15 ft |

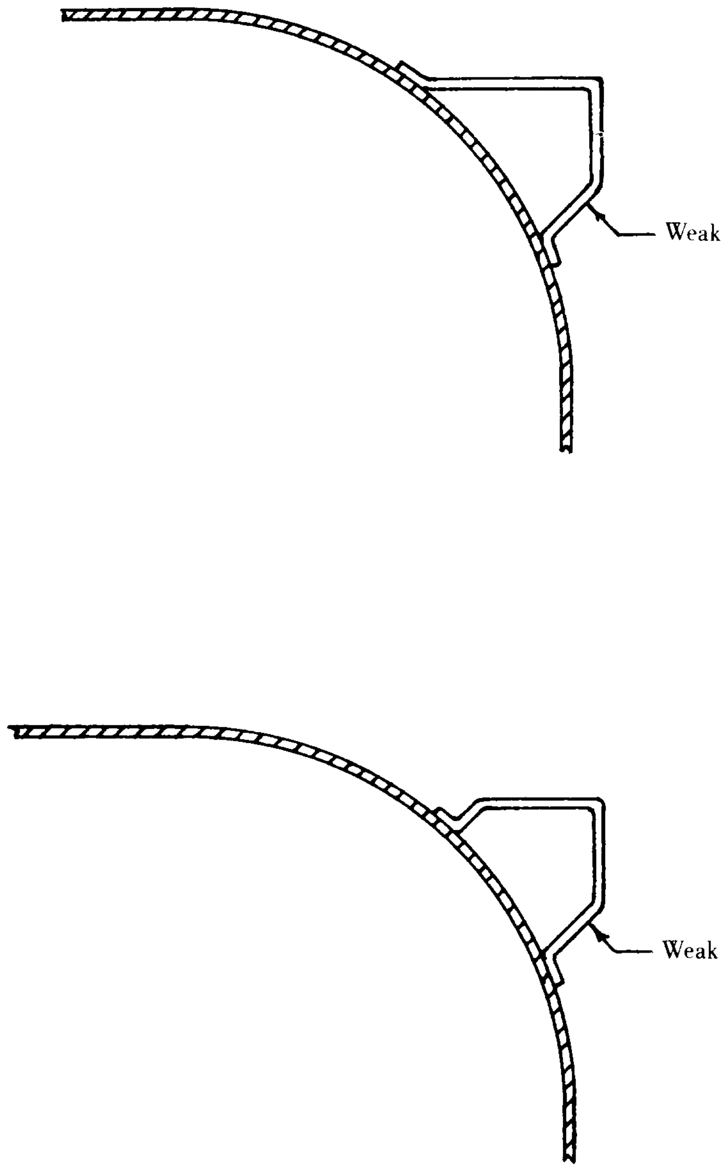



Figure 9-16. Undesirable Stacking Pad Designs

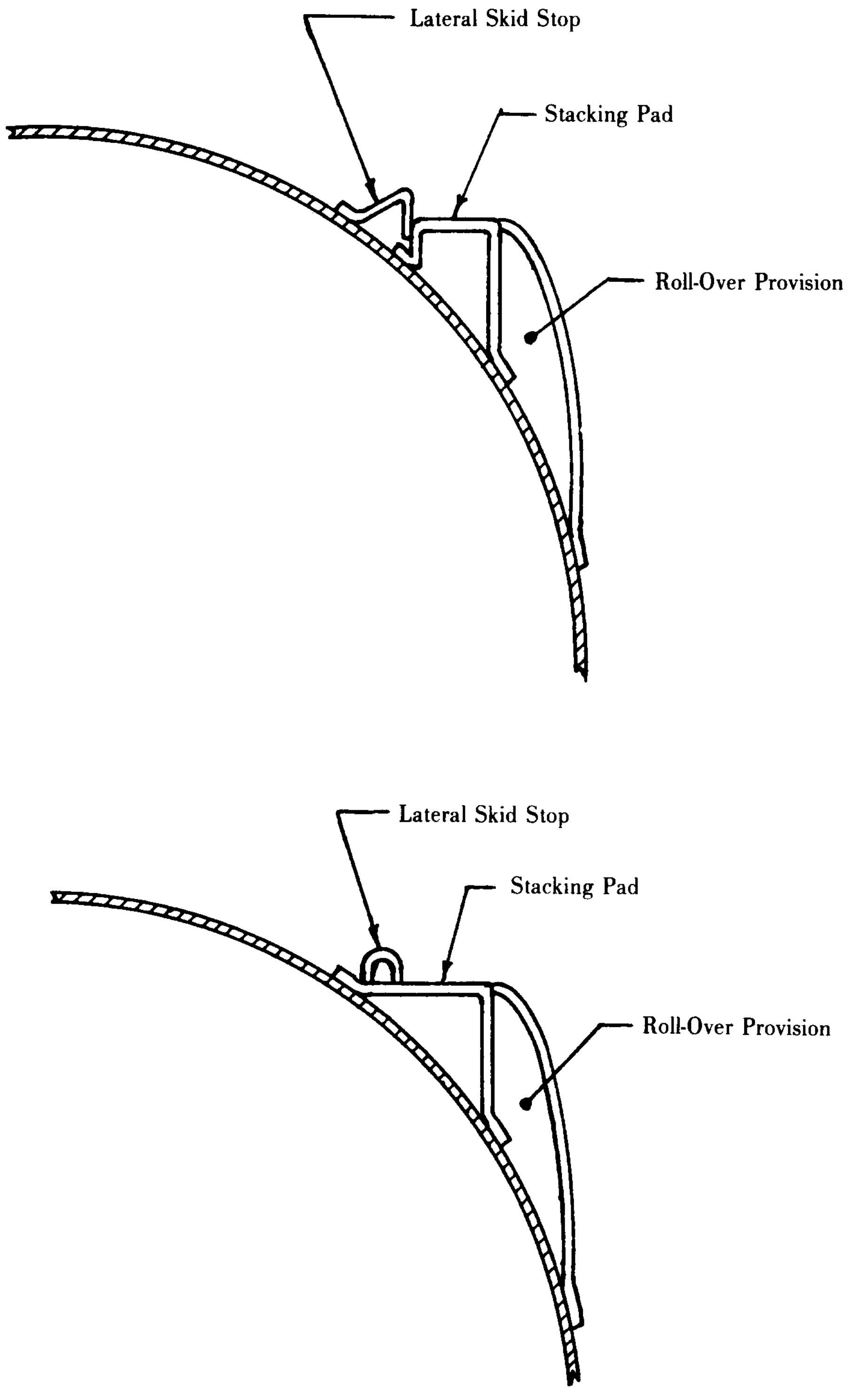



**Figure 9-17. Acceptable Stacking Pad Designs**

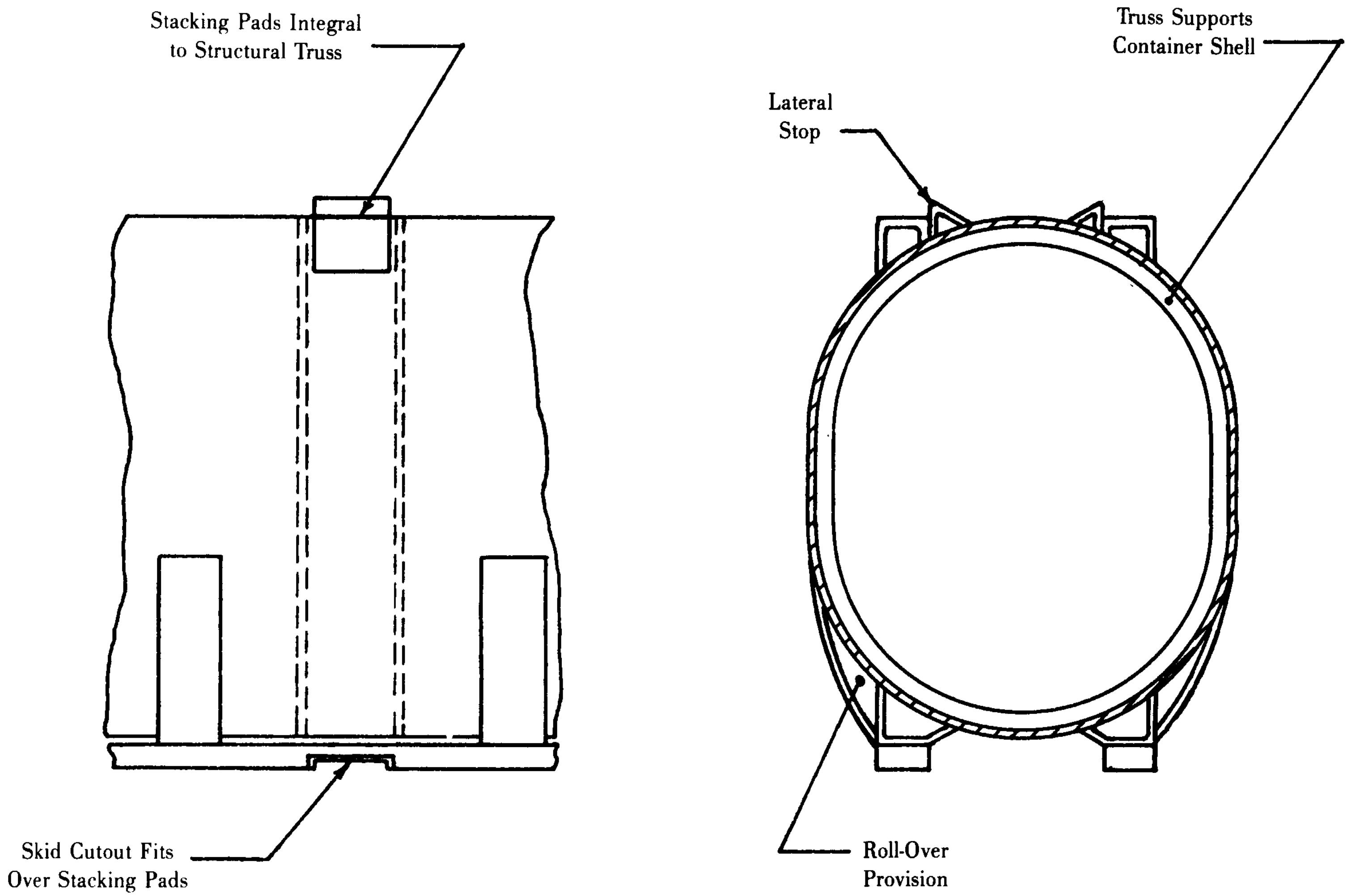



**Figure 9-18. Container Incorporating Roll-Over Provisions and Structural Trusses**

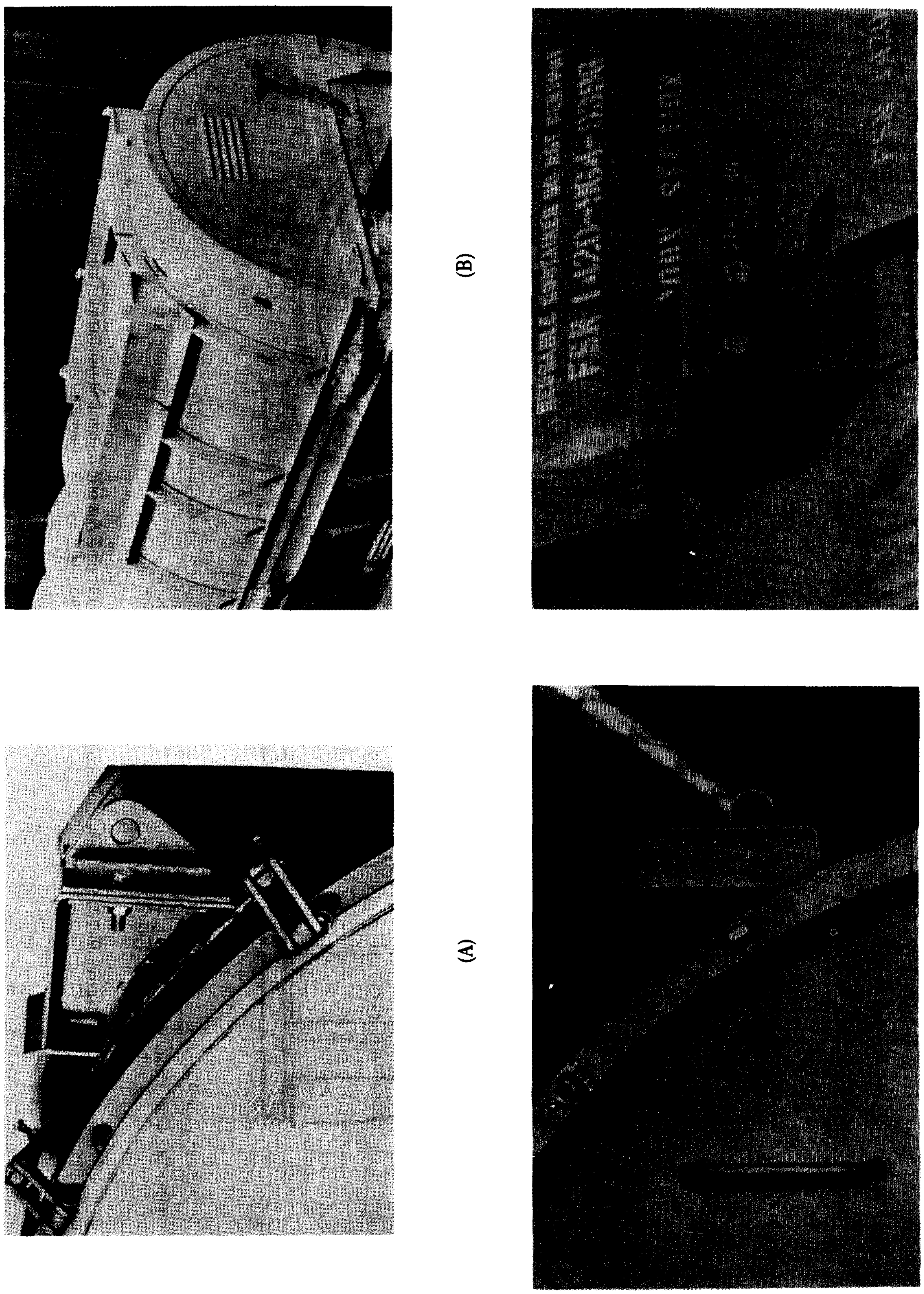
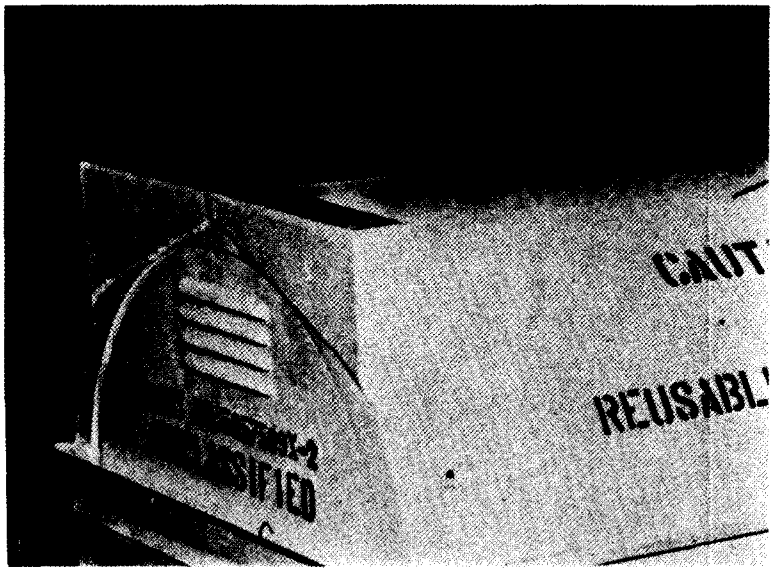
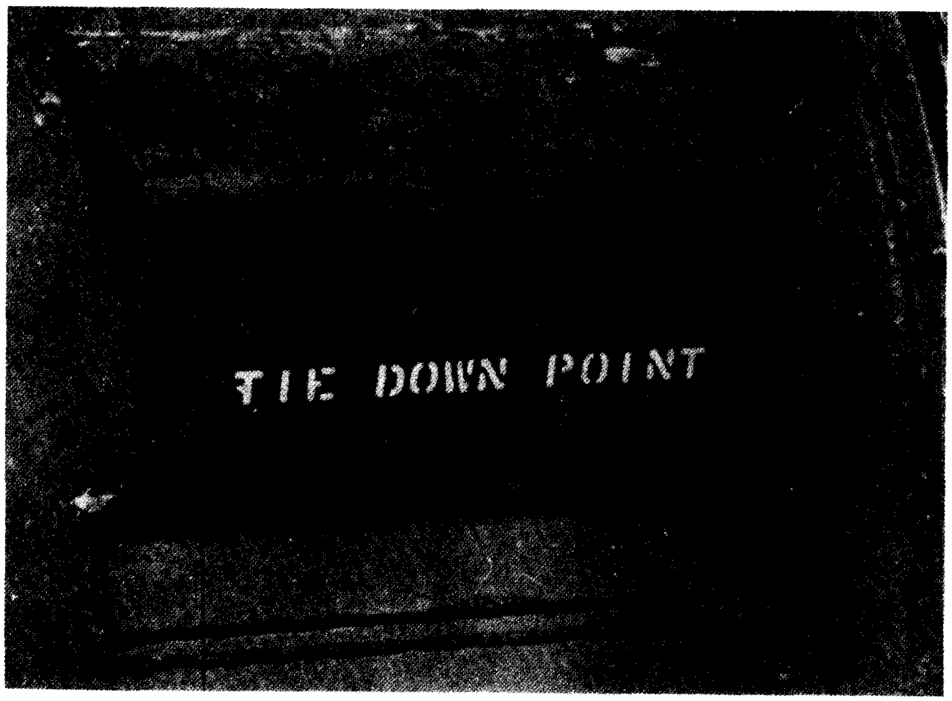



Figure 9-19. Preferred Stacking Pad Designs



(A)




(B)

**Figure 9-20. Inadequately Designed Stacking Pads**

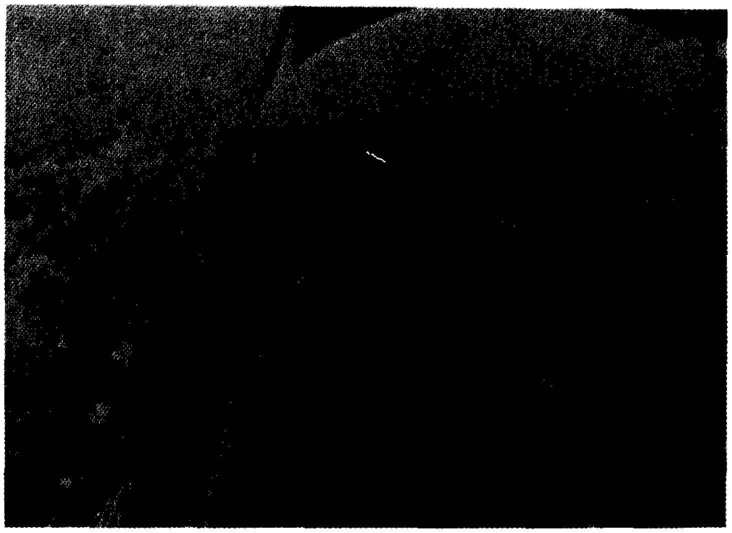


Figure 9-21. Damage Due to Lack of Structural Members

Figure 9-22. Damage Due to Inadequately Designed Stacking Pad

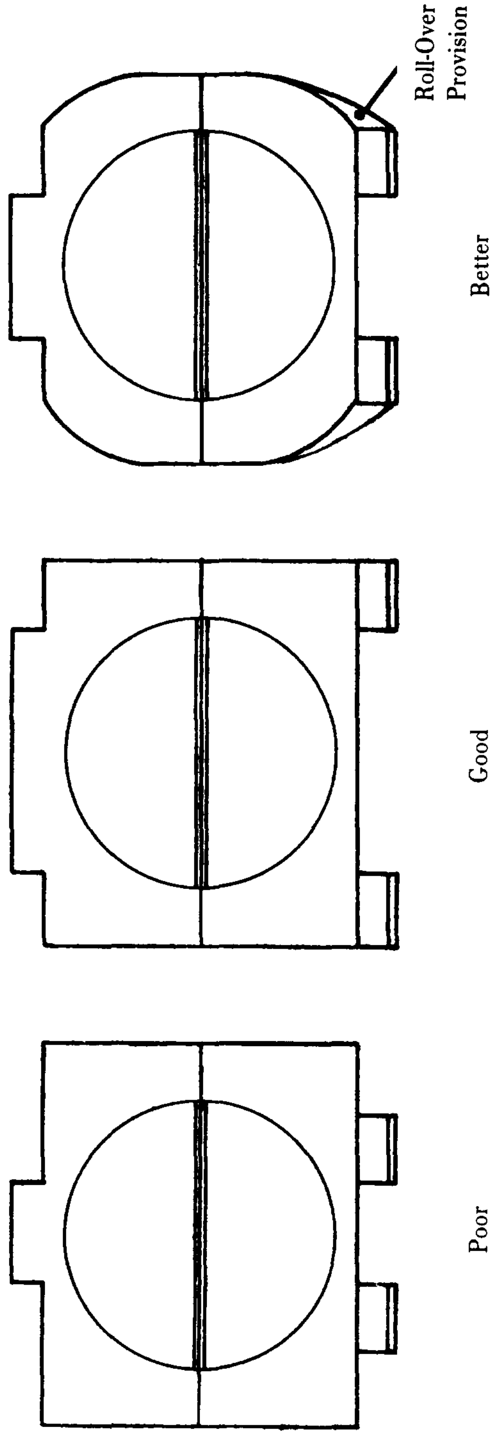
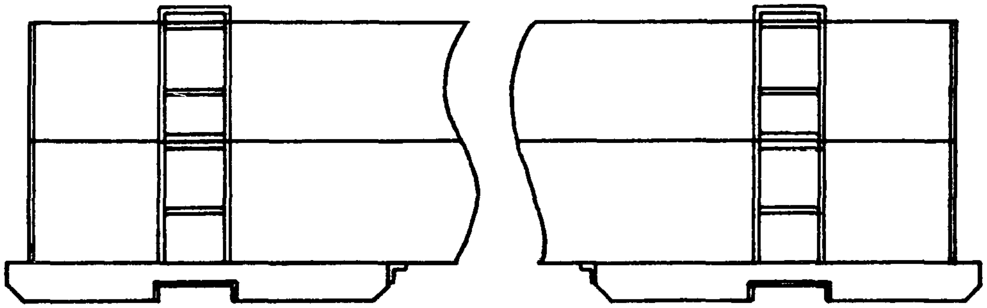


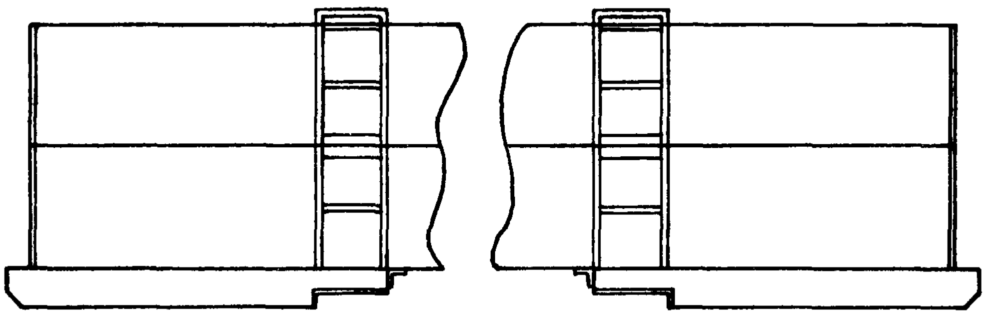

**Figure 9-23. Skid Spacing**

Stacking pad fits
in skid cutout

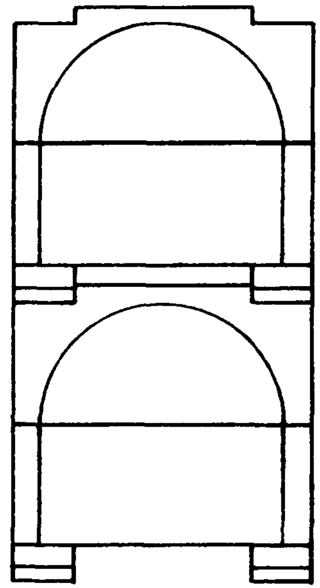


(A) Cutout Skids

Stacking pads fit
between skid steps



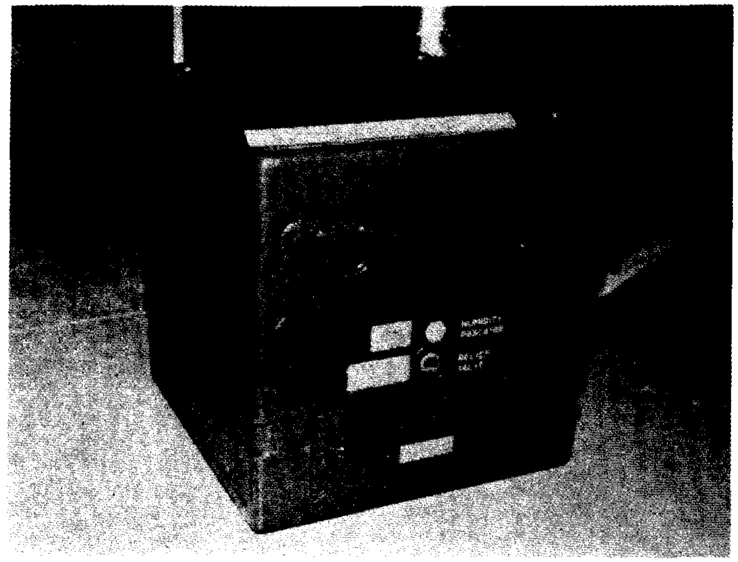
(B) Stepped Skids



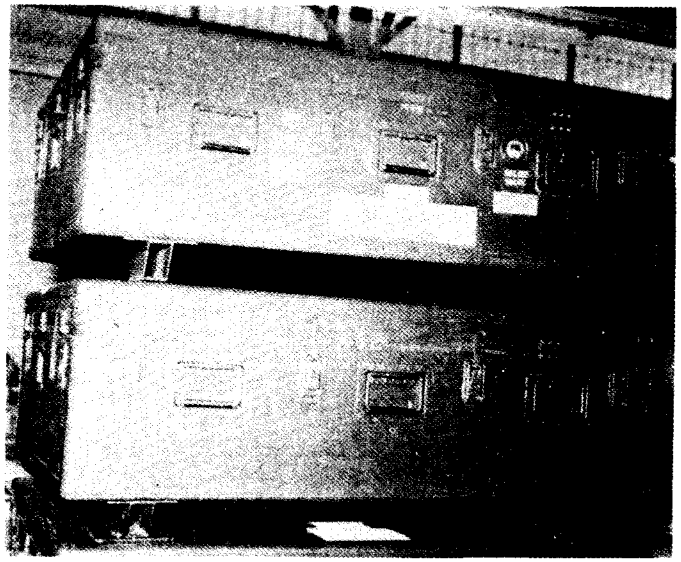
(C) End View of Either
Type Stacked

**Figure 9-24. Stacking Pad Skid Configurations**

(A)



(B)



(C)

**Figure 9-25. Small Containers Incorporating Stacking Provisions**

# CHAPTER 10
# BREATHING AND DEHUMIDIFICATION

*The problem of dehumidification of containers is treated. Procedures for the use of silica gel as a desiccant are given together with example problems for determining the quantity of silica gel required. Advantages/disadvantages of the various types of humidity indicators, holders, and location are presented.*

## 10-0 LIST OF SYMBOLS

$A$ = surface area of moisture barrier, $ft^2$

$C$ = reactivation constant for silica gel. Determined as 0.312 by experiment.

$d$ = inside diameter of tube, in.

$D$ = weight of dunnage, lb

= storage time, days

$E$ = equilibrium percent water adsorption by silica gel in contact with air at average relative humidity during that part of day when air is drawn into container, expressed as decimal

$F$ = flow rate, $ft^3$/min

$K$ = constant depending on units of $V$

$L$ = length of tube, ft

$M$ = weight of gas, lb

= weight of water required to saturate one pound of dry air at temperature $T_2$, lb water/lb dry air

= weight of confined atmosphere

$p$ = pressure differential between two ends of a tube, psi

$P$ = weight of silica gel required, lb

= total pressure inside closed container of a mixture of dry air and water vapor, $lb/ft^2$

$P_a$ = partial pressure of air, $lb/ft^2$

$P_w$ = partial pressure of water, $lb/ft^2$

$\Delta P$ = change in pressure per 1000 ft of elevation, %

$R$ = average relative humidity of ambient air drawn into container, expressed as a decimal

= gas constant, ft•lb/(lb•°R)

= rate of change of altitude, 1000's of ft/min

$S_3$ = volume occupied by one pound of dry air at temperature $T_3$, $ft^3$/lb dry air

$T$ = temperature of gas, °R

$T_1$ = average daily high temperature inside container, °R

$T_2$ = average daily ambient low temperature, °R

$T_3$ = arithmetic average daily ambient temperature, °R

$U$ = number of units of desiccant required

$V$ = volume of gas, $ft^3$

= effective volume of container, $ft^3$ or $in^3$

= container volume, $ft^3$

$W$ = weight density of air entering or leaving tube, $lb/ft^3$

$X$ = constant depending on type of dunnage

## 10-1 GENERAL

As a result of evaporation, the atmosphere in which we live always contains some moisture in the form of an invisible vapor. The amount of water vapor contained in a unit of atmosphere is a function of the temperature. As the water vapor becomes more dense, the pressure it exerts becomes greater until the air has absorbed all of the vapor possible at that temperature at which time the air is said to be saturated.

The volume of atmosphere confined within a sealed container consists of a mixture of dry air and water vapor, each contributing to the total pressure an amount equal to that it would exert if allowed to occupy the entire space alone, i.e.,

$$P = P_a + P_w \tag{10-1}$$

where

$P$ = total pressure
$P_a$ = partial pressure of air
$P_w$ = partial pressure of water.

This is Dalton's Law. It has been found by test that the saturated vapor pressure of a liquid has materially different values when measured at different temperatures. A rise in temperature causes the confined atmosphere to become less dense and is accompanied by an increase in pressure. A fall in temperature increases the density of the mixture and, if the

temperature falls to a sufficiently low value, the atmosphere becomes saturated and the vapor begins to condense forming corrosive dew. Also at this temperature level, the pressure exerted by the confined gas is reduced and may result in a vacuum.

The Ideal Gas Law, which merges the relations discovered by Boyle and Charles, establishes the relation between pressure $P$, volume $V$, and absolute temperature $T$ of a fixed weight $M$ of atmosphere:

$$PV = MRT. \tag{10-2}$$

For a given weight of confined atmosphere, as in a structurally rigid container, the constant $MR$ and the volume $V$ are fixed values; consequently, the relationship becomes:

$$\frac{P}{T} = \frac{MR}{V} = \text{constant.} \tag{10-3}$$

Therefore, $T$ is directly proportional to $P$.

Since temperature $T$ is directly proportional to the pressure $P$, it is evident that as the temperature rises, the pressure of the confined atmosphere increases; and as the temperature drops, the pressure decreases.

In addition to temperature fluctuation, the effect of pressure variation as a function of altitude is of concern to the container developer (see Table 10-1). At sea level, the atmospheric pressure is approximately 14.7 psi and decreases with elevation to a value of approximately 4.4 psi at 30,000 ft. As such, a sealed container must be capable of withstanding this pressure differential in addition to the effects of the temperature variance of these altitudes (see Table 10-2).

The combination of these physical phenomena (thermal, humidity, and elevation) and their effects upon the container and its contents are of prime concern to the designer.

One of the many functions of a container is to protect its contents from the deteriorating effects of moisture without compromising those characteristics favorable to the logistic aspects of worldwide distribution. A container subject to worldwide distribution will, at some time, be exposed to any or all of the conditions resulting in the phenomena previously described.

Early efforts to protect sensitive and sophisticated materiel employed a pressurized sealed container purged of moisture-laden atmosphere. The need for a perfect seal and a structurally sound container body imposed a weight penalty not compatible with an economical logistic pattern. The sealing effectiveness was marginal and the resultant weight required to withstand the pressure differential was considered objectionable, particularly when subject to air transport.

**TABLE 10-1**
**ALTITUDE/PRESSURE CHART**

| Altitude, ft | Pressure, psia | Change Per 1000 ft,% |
|---|---|---|
| 0 | 14.7 | — |
| 1,000 | 14.2 | 4 |
| 2,000 | 13.7 | 4 |
| 3,000 | 13.2 | 4 |
| 4,000 | 12.7 | 4 |
| 5,000 | 12.2 | 4 |
| 7,500 | 11.1 | |
| 10,000 | 10.1 | |
| 12,500 | 9.17 | |
| 15,000 | 8.30 | |
| 17,500 | 7.50 | |
| 20,000 | 6.76 | |
| 25,000 | 5.46 | |
| 30,000 | 4.37 | |
| 35,000 | 3.47 | |
| 40,000 | 2.73 | |
| 45,000 | 2.15 | |
| 50,000 | 1.69 | |

To provide a lightweight effective container, capable of performing its protective functions in a worldwide distribution environment, a new concept was developed—that of *free breathing*. Free-breathing containers are based on the use of tubes open to the atmosphere which allow the container to "breathe" when subject to pressure differentials. The tubes, open to the atmosphere, provide an air passage to equalize the internal and external pressures of the container. This technique permits the use of thinner, lighter weight materials and precludes the need for a perfect seal. The tubes provide an air passage but, by design, impede the transfer of moisture vapor. An empirical ratio of 1:10 has been established for the tube diameter to minimum length. The tubes may be bent to restrict the entrance of rain or sea water; however, any trapped water may freeze during airlift, destroying the ability of the container to breathe.

The present state of the art makes available high flow breather valves to permit application of the controlled-breathing technique. These valves (pressure and vacuum relief) constantly adjust the container

TABLE 10-2
ALTITUDE/TEMPERATURE CHART

| Altitude, ft | Temperature, °F | |
|---|---|---|
| | *Cold Atmosphere | *Hot Atmosphere |
| 0 | -60.0 | 100 |
| 1,000 | -46.5 | 99.2 |
| 2,000 | -33.0 | 95.4 |
| 3,000 | -19.3 | 91.5 |
| 4,000 | -15.0 | 87.6 |
| 5,000 | -15.0 | 83.7 |
| 7,500 | -15.0 | 73.8 |
| 10,000 | -15.0 | 63.9 |
| 12,500 | -20.8 | 54.5 |
| 15,000 | -29.1 | 44.9 |
| 17,500 | -37.5 | 35.1 |
| 20,000 | -46.1 | 25.5 |
| 25,000 | -63.9 | 6.7 |
| 30,000 | -82.3 | -12.3 |
| 35,000 | -85.0 | -30.1 |
| 40,000 | -85.0 | -44.8 |
| 45,000 | -98.6 | -42.6 |
| 50,000 | -122.9 | -40.2 |

*Probable extreme minimum and probable extreme maximum temperatures.

pressure to changes in the atmospheric pressure and prevent excessive pressure differentials during airlifts. Controlled breathing in conjunction with the use of a dehydrating agent minimizes the corrosion introduced by excessive humidity. Controlled breathing permits the use of lightweight materials, minimizes the complexity of the system, and results in less hazardous operation.

Sealed containers exposed to the 24-h diurnal cycle subject the encased atmosphere within their confines to fluctuations in pressure. As the temperature of the external environment rises and falls during a 24-h period (diurnal cycle), the internal temperature of the container also will rise and fall. It has been shown that the pressure varies directly as the temperature and, as the temperature rises, the internal pressure increases. Also, as the temperature drops, the internal pressure decreases proportionately. A perfectly sealed container must provide sufficient structural rigidity to withstand the effects of pressure fluctuation caused by the diurnal cycle. In addition, the change in temperature of the encased air may approach the dew point and cause condensation of the suspended water vapor. This small amount of condensate can be conveniently and effectively absorbed by desiccants, a dehumidification technique to be discussed in subsequent paragraphs of this chapter. A reusable sealed container is both logistically and economically unfeasible. The level of protection initially provided will gradually diminish as the result of gasket and seal deterioration and will in time perform as an imperfectly sealed structure or free-breathing container. Consequently, the perfectly sealed container is not recommended and is discussed only for its historical significance.

Imperfectly sealed containers, both free and controlled breathing, will, when heated, exhaust air from within their confines. Conversely, as the air cools, the internal pressure will drop and thus create a vacuum that causes air to enter the confines of the container. In effect, the container breathes and, by so doing, maintains equilibrium between the internal pressure of the container and the atmospheric pressure of its environment. Consequently, free-breathing containers are not exposed to a pressure differential and the destructive stresses imposed upon a sealed structure. The controlled-breathing technique minimizes the pressure differential and subjects the structure to negligible stress loads.

The advantages provided by controlled and free breathing are unfortunately offset by the periodic introduction of new moist air that must be purged of its moisture content. The new air, introduced by the breathing cycle, can be effectively dehumidified by desiccants.

*Fundamentals of Guided Missile Packaging* includes the following statement: "An indoor temperature rise of 5 deg F will force approximately 1% of the contained air out of an imperfectly sealed structure.". It may be assumed that the reverse is true and that, with a temperature drop, the same amount of air as that exhausted will be replaced by moist air entering. In certain environments (desert) it is not uncommon to experience a 50-deg F temperature drop during the diurnal cycle. Based on the given ratio of 1:5, the container will exhaust and replace 10% of its initial volume during a 24-h period; consequently, the moist air entering must be dehumidified.

In addition to the amount of air displaced and replaced by the phenomenon of breathing, of prime concern is the rate at which breathing is performed. In certain situations (rapid descent of cargo aircraft, abnormal temperature drops, etc.), those factors affecting the breathing cycle may change radically and within a matter of minutes. The flow of air through

the breather ports or valves must be adequate to avoid subjecting the container structure to the destructive forces of a momentary pressure differential. The rate of flow of this breather air is a function of the pressure difference between the container and the ambient air; this pressure difference is, in turn, a function of the rate of ascent of the particular aircraft.

## 10-2 BREATHING AND ITS RAMIFICATIONS

### 10-2.1 TYPES OF CONTAINERS

In addition to those characteristics discussed in previous chapters, the missile container may be further classified as to its ability to provide climatic protection. The most common types are listed in an order reflecting the progressive level of protection provided:

a. Open containers
b. Vented containers
c. Free-breathing containers
d. Controlled-breathing containers
e. Sealed containers.

Each type is discussed in the paragraphs that follow.

#### 10-2.1.1 Open Containers

These containers are merely fixtures which function to support their contents. The containers often are equipped to provide physical and mechanical protection. The container, as such, provides no climatic protection nor does it function to resist exposure of its contents to those elements peculiar to the climatic environment. Any climatic protection provided must be by auxiliary devices (barrier bags, etc.) divorced from and independent of the container *per se*.

#### 10-2.1.2 Vented Containers

These containers provide protection against many of the climatic elements (rain, snow, etc.) but are functionally open to the atmosphere and will not resist the penetration of moisture-laden air. The vents perform to maintain pressure equalization between the interior of the container and the prevalent atmosphere. In addition, the vent holes—usually located in the bottom of the container—serve as drains through which any accumulated condensate may escape. When used, vents should be located to permit the unrestricted drainage of condensate and, yet, not permit the penetration of rain, etc. In addition, drain holes should be screened or baffled to discourage the entry of rodents, snakes, etc.

#### 10-2.1.3 Free-Breathing Containers

These containers are, in essence, vented containers having the additional capability of minimizing the amount of moisture vapor entering the container. This is accomplished by the use of vent tubes whose configuration functions to maintain the humidity level within the container once equilibrium has been established. Vent tubes provide an air passage and are open to the atmosphere but by their design function to impede the transfer of moisture vapor. This feature permits the container to breathe, i.e., to adjust to the variances in atmospheric pressure without exposing the contents of the container to the moisture prevalent under these conditions. Diffusion of water vapor in air is so low that, for practical purposes, insignificant quantities of water vapor will pass through tubes of length ten times the diameter. If a tube is used which has a length determined from two components, i.e., a length sufficient to meet this criterion plus an additional length sufficient to contain the "slug" of air expelled from and later returned to the container, infiltration through the breather will be negligible. Tube length may become very great for large containers and thus be impractical. Tests conducted at the Naval Gun Factory have established an inside diameter of 0.25 in. as minimum for vent tubes to effectively drain any accumulated condensate.

Functioning as an air vent, the tube or tubes must be of sufficient size to permit passage of the displaced air within a reasonable time. The descent of cargo aircraft may subject the container to a rapid change of external pressure if the cargo compartment is not pressurized. It becomes imperative that the internal pressure of the container be equalized and maintained during the external pressure buildup. The ability to react adequately is dependent upon the vent tube diameter. The following derivation is presented to acquaint the designer with the factors affecting the selection of the vent tube diameter:

a. A review of the data contained in Table 10-1 indicates that the most severe change in atmospheric pressure occurs in the first few thousand feet of altitude above sea level. The percent of change, however, remains constant at 4%, and this value has been selected as the maximum rate for determining the flow through vent tubes.

b. Since container breathing is most pertinent to the air transport environment, it becomes essential to establish the rate at which the maximum pressure change will occur. Because of the many variables affecting aircraft ascent—e.g., payload, ambient temperature, altitude of airstrip—the aircraft operational manuals should be consulted for valid ascent data.

c. A relationship has been established* between known factors which, when presented in mathematical form, will permit the designer to calculate the minimum flow through the vent tube to maintain the desired equilibrium, i.e.,

$$F = (\Delta P)RV \tag{10-4}$$

where

$F$ = flow rate, ft$^3$/min
$\Delta P$ = change in pressure per 1000 ft of elevation, %
$R$ = rate of change in altitude, 1000's of ft/min
$V$ = effective volume of the container, ft$^3$ (Use volume of empty container if reusable and subject to air transport in empty condition; otherwise, use effective volume by subtracting the displacement of the contents from the total volume.)

Considering the maximum percent of change in pressure to be $\Delta P$ = 4% per 1000 ft and the rate of change in altitude to be $R$ = 2000 ft/min (maximum rate of ascent for contemporary military cargo aircraft), Eq. 10-4 may be modified to show the relationship between the required flow rate and the effective volume of the container:

$$\begin{aligned} F &= (\Delta P)RV \\ &= (0.04)(2)V \\ &= 0.08V, \text{ ft}^3/\text{min}. \end{aligned} \tag{10-5}$$

d. The ability of a tube to satisfy the required flow rate is dependent upon its diameter. The flow rate within a tube with a comparatively small differential pressure between its two ends may be expressed mathematically by Eq. 10-6 (see *Machinery Handbook*).

$$F = 58\sqrt{\frac{pd^5}{WL}} \tag{10-6}$$

where

$F$ = flow rate, ft$^3$/min
$p$ = pressure differential between two ends of the tube, psi
$d$ = inside tube diameter, in.
$W$ = weight density of the air entering or leaving the container, lb/ft$^3$
$L$ = length of the tube, ft.

*AGM Cargo Ties, Inc. (formerly Arizona Gear Manufacturing Company)

Eq. 10-6 may be modified to permit direct calculation of the minimum tube diamater. Since the ratio of length to diameter has been established as 10 to 1, $L$ may be expressed in terms of $d$ and in the same units:

$$L = 10d/12 = 5d/6.$$

Therefore:

$$F = 58\sqrt{\frac{pd^5}{W(5/6)d}}$$

$$d = (0.000248F^2W/p)^{1/4}, \text{ in.} \tag{10-7}$$

An example problem follows.

*Given:*

Container volume $V$ = 42.4 ft$^3$; is reusable; will be returned empty by air transport.

Cargo aircraft is C-130 whose rate of ascent is within established 2000 ft/min.

Pressure differential $p$ assumed to be 1 psi (internal pressure of the container at sea level and the pressure at 2000 ft of elevation — see Table 10-1).

Weight density of air $W$ = 0.076 lb/ft (Density varies, depending on prevailing altitude, temperature, and relative humidity. MIL-STD-210 assists in the selection of a suitable value.)

*Object*: To find the minimum diameter $d$ of the vent tube to protect the container.

By Eq. 10-5, find the rate of air flow $F$ necessary to maintain pressure equilibrium between the confines of the container and the prevalent atmosphere.

$$F = 0.08(42.4) = 3.39 \text{ ft/min}.$$

To calculate $d$, use Eq. 10-7.

$$d = \left[\frac{0.000248(3.39)^2(0.076)}{1}\right]^{1/4} = 0.121 \text{ in.}$$

The minimum tube diameter required has been calculated as 0.121 in.; however, it has been determined previously that to permit tube condensate drainage, the tube diameter can be no smaller than 0.25 in. Consequently, a vent tube having an inside diameter of 0.25 in. should be used and, applying the established 10 to 1 ratio, the length of the tube shall be no less than 2.5 in. An additional length should be provided sufficient to contain the "slug" of air expelled from and later returned to the container as discussed previously. A large increase in length necessitates the recalculation of the flow rate to insure that the diameter is adequate.

*Note:* Free-breathing containers should be equipped with an effective seal to assure that the majority of displaced air will pass through the vent tube and be subjected to the dehumidification discussed in subsequent paragraphs of this chapter.

### 10-2.1.4 Controlled-Breathing Containers

These containers are a sophisticated version of the free-breathing container, and the required rate of flow can be calculated in the same manner as previously discussed. The breathing of the containers is accomplished by incorporating into the assembly a precision valve or valves calibrated to open and/or close when subjected to a pressure differential. The state of the art makes available an assortment of commercial valves rated according to their flow capacity and sensitivity to pressure change. MIL-V-8712 classifies and establishes the performance characteristics of low pressure air relief valves.

There are valves available which will open or "crack" when subjected to a positive pressure. There are valves which will "crack" when subjected to a negative pressure or vacuum. In addition, there are combination valves (Fig. 10-1) which "crack" under both conditions. The valves or valve will, when installed, function to regulate the internal pressure of the container by "cracking" to either exhaust or take in air when a variance in pressure is induced by a change in altitude or temperature fluctuation.

A container equipped with controlled-breathing valves, when closed and sealed at sea level, will have an internal pressure of approximately 14.7 psi. When subjected to an air lift, and upon attaining an altitude of 4000 ft, it will be subjected to an external pressure of 12.7 psi (see Table 10-1). When exposed to these conditions, the container is said to be under a pressure differential of 2 psi (14.7 – 12.7). The internal pressure variance causes the positive pressure breather valve to "crack", thus exhausting air from within the confines of the container. Upon discharge of air, the container experiences an internal pressure drop. The valve remains open until the internal pressure has stabilized to a level equal to or slightly less than the external pressure of the atmosphere, at which time it closes. Similarly, the negative pressure breather valve will function under the opposite conditions as experienced during descent of the aircraft. The atmospheric pressure at sea level is greater than

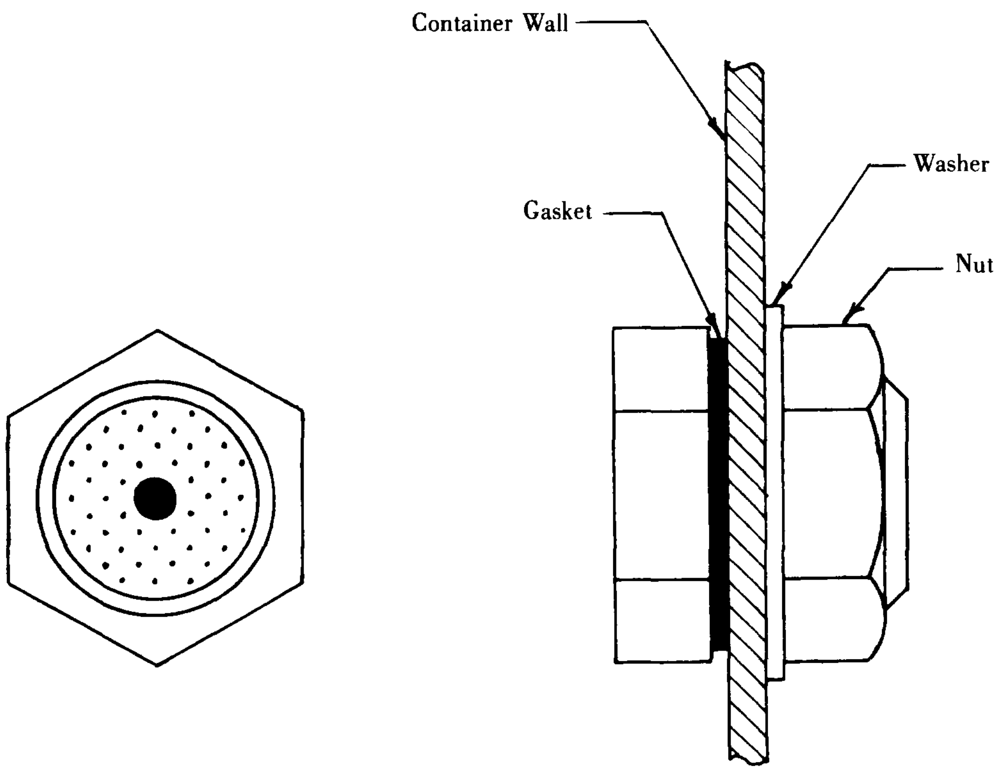



**Figure 10-1. Typical Pressure Relief Valve**

the adjusted internal pressure of the container, and the valve "cracks" to suck in air and maintain pressure equilibrium.

The sensitivity of the valve can be calibrated and set to respond to a particular range of pressure differential. The recommended setting has been found to be +2.5 psig and -2.5 psig. Exhaust valves should be set to "crack" when subjected to a pressure variance of +2.5 psig. Intake valves should be set to "crack" when subjected to a vacuum of -2.5 psig.

As breather valves function to introduce new air into the confines of the container, a dehumidifier will be required to purge the new air of its moisture content.

The choice of a combination two-way valve or two one-way valves is a matter of economics; however, a manual release should be provided under either condition to bleed off residual pressure or vacuum prior to the opening of the container.

### 10-2.1.5 Sealed Containers

These containers refer to those purged of air by the introduction of pressurized dry gas. The effectiveness of pressurization is dependent upon the quality of the container seal, and any protection provided is marginal. This technique results in a heavy structurally rigid container not compatible with the logistic requirements of a mobile Army. The sealed container is mentioned only for its historical significance and is not recommended for missile applications.

## 10-2.2 DEHUMIDIFICATION

### 10-2.2.1 General

Moisture-laden air, encased within or introduced into, the confines of a container must be purged of its moisture content. The air must be dehumidified to protect the contents from the corrosive effects of the condensate which will ultimately form when the container is exposed to the environment of its logistic pattern.

Dehumidification is accomplished by the use of a desiccant which, having an affinity for water, will extract the moisture from the air within its sphere of influence. Desiccants used for military packaging usually are chemical agents satisfying the performance requirements of MIL-D-3464.

The performance of a desiccant is based on the principle of partial pressure. A volume of moisture-laden air, when confined, exerts a pressure comprised of the partial pressure of its dry air content and the partial pressure of its water vapor content (see Eq. 10-1). The affinity of a desiccant for water is due to the pressure differential of the water vapor content of the desiccant and that of its atmosphere. Water vapor will diffuse from the relatively higher partial vapor pressure of the moist air to the lower level of the desiccant until dynamic (psychrometric) equilibrium is attained and no further net transfer takes place. This phenomenon is known as adsorption and results in a reduction in the moisture content of the air exposed to the action of the desiccant.

There are many compounds which will function as a desiccant; however, that used most extensively in military packaging is silica gel. Silica gel is commercially available from numerous sources, and its performance and application are effectively regulated by the following documents:

a. MIL-D-3464, *Desiccants, Activated, Bagged, Packaged Use and Static Dehumidification*

b. MIL-P-116, *Preservation Packaging, Methods of.*

Silica gel is a granular, amorphous form of silica, made from sodium silicate and sulfuric acid. It has an almost infinite number of submicroscopic pores that attract water vapor, condense it, and hold it as a liquid by the physical phenomena known as surface adsorption and capillary condensation. It can adsorb approximately 40% of its weight of moisture at 100% relative humidity. The adsorption process is purely physical; therefore, harmful compounds are not formed when water is adsorbed. The volume of silica gel remains unchanged as water is adsorbed. Saturated silica gel neither appears nor feels wet. It will however dissolve if soaked and, therefore, should never be located in the container where it will come into direct contact with any accumulation of condensate. Silica gel is available in a variety of particle sizes. However, under static equilibrium conditions the size and shape of particles are usually unimportant. A few properties of silica gel are shown in Figs. 10-2 and 10-3.

The process of adsorption and activation are completely reversible. As a result, silica gel can be reactivated an unlimited number of times without loss in efficiency or adsorption capacity.

### 10-2.2.2 Application

Desiccant dehumidification can be applied by static, automatic, or dynamic means as follows:

a. Dynamic Dehumidification. In this process machinery is employed to remove excess moisture from an enclosure. Normally, the air to be dehumidified is drawn from the enclosure and forced through a bed of desiccant where it is dehumidified. The dried air is returned to the enclosure where, after collecting ad-

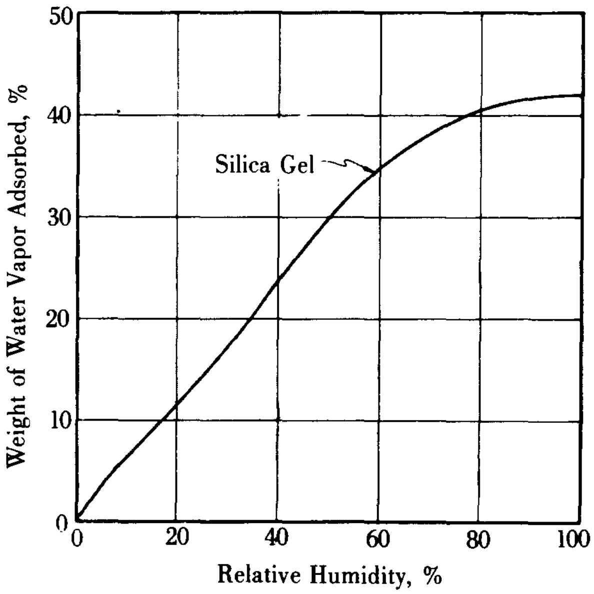



**Figure 10-2. Equilibrium Adsorption Capacity of Silica Gel**

ditional moisture, it is again recirculated through the machine. Generally, dynamic dehumidification is used in the dehumidification of large spaces, over 4000 $ft^3$ in volume. Since missile and rocket containers are well below this volume, they can be dehumidified using automatic or static dehumidification.

b. Automatic Dehumidification. This refers to a solar radiation breather in which air drawn into an enclosure is forced to pass through a bed of desiccant, usually silica gel. Therefore, only dry air can enter during in-breathing. During out-breathing, solar radiation is used for the reactivation of the desiccant.

c. Static Dehumidification. This process employs a quantity of activated desiccant placed in the space to be dehumidified. The initial charge must be sufficient not only to reduce the relative humidity of the air, but also to remove any water which may be present in or on the item stored.

Containers equipped with either free- or controlled-breathing devices will require considerably more desiccant than those that are hermetically sealed and, in addition, will require periodic inspection to assure effective performance of the desiccant. Indicators and detectors are available which will automatically register to show, by visual inspection, that the desiccant has become saturated and its affinity for moisture has been exhausted.

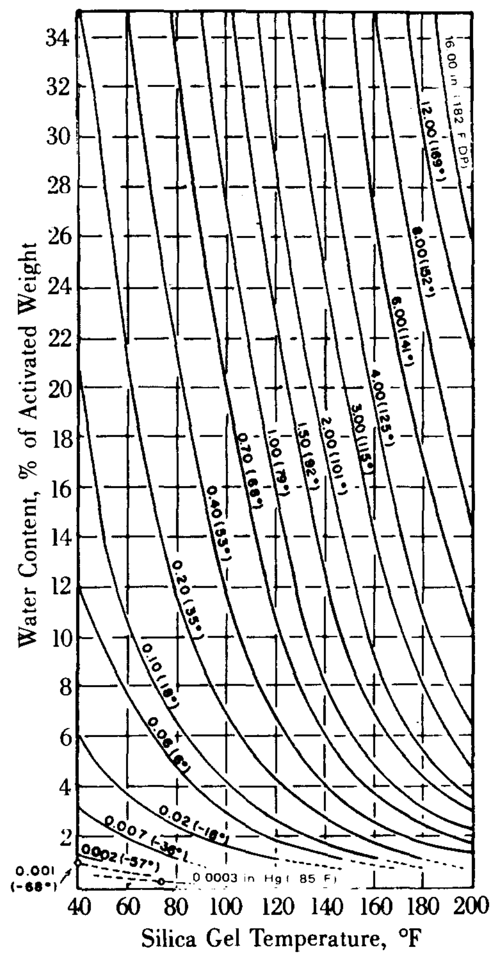



**Figure 10-3. Water Capacity of Silica Gel as a Function of Temperature at Various Partial Pressures (equilibrium isopiestics) (Dew points corresponding to partial pressures are given in parentheses on isopiestic lines.)**

The procedure established to regulate the use of desiccants to assure effective application is adequately documented. Standards have been established and equations developed to assist in the selection of the amount of desiccant required for the various conditions and amount of air to be dehumidified.

MIL-D-3464 defines the unit weight of a desiccant and specifies that the unit weight shall not exceed 50 grams. Since the unit weight will vary with the capacity adsorption of the specific desiccant agent, general calculations must consider the maximum weight which may be used. Consequently, the subsequent equations will consider a unit of desiccant as 50 grams.

#### 10-2.2.3 Desiccant Requirements

#### 10-2.2.3.1 For Sealed Containers

MIL-P-116 presents two equations which apply only to sealed containers where the vapor transmission rate of the barrier material used is so low as to be considered negligible. Under these conditions, the desiccant will be required only to dehumidify the encased air and will *not* be subject to any appreciable amount of additional moisture vapor introduced after sealing.* The equations follow:

Equation No. I. To find the units of desiccant for use within *flexible sealed moisture barriers* other than rigid metal containers:

$$U = CA + XD. \tag{10-8}$$

Equation No. II. To find the units of desiccant for use within *sealed metal containers* functioning as *rigid* moisture barriers:

$$U = KV + XD \tag{10-9}$$

where

$U$ = number of units of desiccant required
$C$ = 0.011 when area of barrier is expressed in $in^2$
$C$ = 1.6 when area of barrier is expressed in $ft^2$
$A$ = surface area of the moisture barrier, $ft^2$
$D$ = weight of dunnage (cushions, braces, supports, etc.) other than metallic objects encased within the barrier, lb
$V$ = volume of the container, $in^3$ or $ft^3$
$K$ = 0.0007 when volume is expressed in $in^3$
$K$ = 1.2 when volume is expressed in $ft^3$
$X$ = 0.5 for synthetic foam or rubber dunnage
$X$ = 2 for glass fiber dunnage
$X$ = 6 for bound fiber (hair) dunnage
$X$ = 8 for felt, wood, or cellulosic dunnage.

*When sealed containers are subjected to periodic inspection or their seal is broken at any time, the initial desiccant charge must be replaced by either a new or reconstituted desiccant.

#### 10-2.2.3.2 For Free- or Controlled-Breathing Containers

The desiccant used in conjunction with free- or controlled-breathing containers must have sufficient adsorption capacity to dehumidify not only the initial air encased within the container but also that additional air which will be introduced by the breathing process. The units of desiccant required to dehumidify the initial air can be determined by applying Eq. 10-8 or Eq. 10-9.

Additional units of desiccant will be required to compensate for the breathing experienced during *long-term storage* and/or the *diurnal cycle*. The additional units of desiccant required to protect under these conditions may be determined by the use of the following equation (see *Fundamentals of Guided Missile Packaging*, by Klein):

Equation III (*Note*. Applies to silica gel desiccant)

$$P = \left[\frac{2VT_3\,(T_1 - T_2)\,DMR}{T_1T_2S_3E}\right](1 - C) \tag{10-10}$$

where

$P$ = weight silica gel required, lb
$V$ = volume of container, $ft^3$
$T_1$ = average daily high temperature inside side container, °R (Found by subtracting daily low ambient temperature from daily high ambient temperature, multiplying by differential factor—1.6 in spring, 2.0 in summer, 1.6 in fall, and 1.2 in winter —and adding to $T_2$.) (Climatic extremes for military equipment can be found in MIL-STD-210.)
$T_2$ = average daily ambient low temperature, —R
$T_3$ = arithmetic average daily ambient temperature, °R
$D$ = storage time, days
$M$ = weight of water to saturate one pound of dry air at temperature $T_3$, lb of water/lb of dry air
$R$ = average relative humidity of ambient air being drawn into container, expressed as a decimal
$C$ = reactivation constant for silica gel. Determined as 0.312 experimentally.
$S_3$ = volume occupied by one pound of dry air at temperature $T_3$, $ft^3$/lb of dry air

$E$ = equilibrium percent water adsorption by silica gel in contact with air at average relative humidity during that part of the day when air is drawn into container, expressed as a decimal.

In Eq. 10-10, the number 2 is an empirical factor of safety necessitated by the number of assumptions required. For outdoor storage under tropical conditions ($T$ = 80° to 135°F, RH = 90%), it is estimated that the quantity of silica gel should be 0.273 lb/ft$^3$·yr.

For complete projection encompassing all the environments peculiar to worldwide distribution, the desiccant charge must include sufficient units to provide for the many changes of air which the container may experience when subjected to rapid variations in atmospheric pressure peculiar to the air transport media environment. The amount of additional desiccant required may be determined by estimating the number of flights that the container will experience during the delivery phase of its logistic cycle. As the container gains altitude, the pressure inside exceeds the external ambient pressure and the container exhales at intervals set by the sensitivity of the pressure relief valve if the container is of the controlled-breathing type. If the container is free breathing, it will exhale constantly. When gaining altitude, the container exhales dry desiccated air; however, in descent, the container will inhale moist air. From Table 10-2 and similar data the external temperature at any altitude can be found. With a psychrometric chart, the water content in weight per unit volume of air can be determined. Calculate the quantity of air inhaled by applying the general gas laws. The quantity of inhaled air having been determined, the amount of desiccant required to remove the water content of the inhaled air can be calculated. This desiccant should be added to that required for initial and storage desiccation.

In summation, one may consider the amount of desiccant used as a function of the container and its moisture barrier characteristics, and of the environment in which the container will operate. Overall, worldwide protection must consequently provide for either or all of the following:

a. Initial desiccation—the removal of moisture present when the container is sealed

b. Transportation desiccation—the protection needed during shipping

c. Storage desiccation—the protection needed during container storage.

#### 10-2.2.3.3 Example Problems

Illustrative examples of the procedures used in calculating desiccant requirements of containers follow:

a. Example No. 1:

*Given:* Shipment enclosed in a rectangular, flexible sealed moisture barrier 24 in. × 36 in. × 18 in. and contains 10 lb of wood dunnage—i.e., $X = 8$ and $D = 10$.

*Object:* Calculate number of units $U$ of desiccant required.

The amount of desiccant required for this type of package depends on the surface $A$ of the moisture barrier and the weight $D$ of the dunnage within the barrier.

The surface area $A$ is

$$A = 2[(24)(18) + (36)(18) + (24)(36)]/144 = 27 \text{ ft}^2.$$

For this type of package, the desiccant requirement is calculated by Eq. 10-8.

$$U = CA + XD = 1.6\,(27) + 8(10) = 123.2 \approx 123 \text{ units of desiccant.}$$

b. Example No. 2:

*Given:* Hermetically sealed aluminum container 12 in. × 12 in. × 48 in., containing 7 lb of fiberglass cushioning— i.e., $X = 2$ and $D = 7$.

*Object:* Calculate number of units $U$ of desiccant required.

The amount of desiccant required for this type of container depends on the volume $V$ of the container and the weight $D$ of the enclosed dunnage.

The volume $V$ is

$$V = 12 \times 12 \times 48/(12)^3 = 4 \text{ ft}^3;$$

therefore, use $K = 1.2$.

For this type of container, the desiccant requirement is calculated by Eq. 10-9.

$$U = KV + XD = 1.2(4) + 2(7) = 18.8 \approx 19 \text{ units of desiccant.}$$

c. Example No. 3:

*Given:* A free-breathing steel cylindrical container 3 ft in diameter and 6 ft long is to be stored for 6 mo in a tropical atmosphere with 90% relative humidity and the temperature varies from 70° to 85°F. The container is sealed in the field at these conditions. Elastomeric mounts are

used for suspending the packaged item. (Note that $D = 0$.)

*Object:* Calculate the amount of silica gel required to prevent corrosion.

Eq. 10-10 will be used to determine the amount of silica gel required; however, this equation assumes the container is dry when sealed. Since this is not the case for this example, the units of desiccant as an initial charge to dry the container are determined by Eq. 10-9.

The volume $V$ of the cylinder is

$$V = \pi\,(d/2)^2 L$$
$$= \pi(3/2)^2\,(6) = 42.4\ \text{ft}^3\text{; therefore, use } K = 1.2.$$

By Eq. 10-9 the units of desiccant required are

$$U = KV + XD$$
$$= 1.2(42.4) + X(0) = 50.88$$
$$\approx 51.$$

Therefore, an initial charge of $U = 51$ units of MIL-D-3464 desiccant required.

Now the additional amount of desiccant to compensate for the breathing experienced during long-term storage can be calculated by Eq. 10-10. The various factors are first determined:

$T_3 = (70 + 85)/2 = 77.5°\text{F}$
$= 77.5 + 460 = 537.5°\text{R}$

$T_1 = (85 - 70)(2.0) + 70$ (Use factor of 2 because of summer climate.)
$= 15\ (2) + 70 = 100°\text{F}$
$= 100 + 460 = 560°\text{R}$

$T_2 = 70 + 460 = 530°\text{R}$

$D = 6 \times 30 = 180$ days

$M = 0.019$ lb water/lb dry air; determined from a psychrometric chart. Dry bulb temperature $= 77.5°$F; wet bulb or saturation temperature $= 75°$F.

$S_3 = 13.8$ ft$^3$/lb dry air at $77.5°$F

$E = 41\%$ water content of activated weight; determined by extrapolating Fig. 10-3, using a silica gel temperature of $77.5°$F and a wet bulb or saturation temperature of $75°$F. This value of $E$ can be checked by using Fig. 10-2 with a relative humidity of 90% since it was derived for a temperature of $77°$F which, by chance, is the condition of this example.

$R = 90\% = 0.90$ (given)

$C = 0.312$ (given).

Substitute into Eq. 10-10:

$$I = \frac{2\,VT_3\,(T_1 - T_2)\,DMR\,(1 - C)}{T_1\,T_2\,S_3\,E}$$

$$= \frac{2(42.4)(537.5)(560-530)(180)(0.019)(0.9)(1-0.312)}{(560)(530)(13.8)(0.41)}$$

1.7 lb silica gel.

### 10-2.2.4 Desiccant Holders

Standard commercial types of desiccant holders, usually cylindrical in configuration, are available. They consist of a perforated holder body, a cover with a sealing gasket, washer, and a nut. Also provided is an "O"-ring seal to be installed between the holder body and the outer container wall. This type of holder is adapted to the container by means of a hole in the container wall (Fig. 10-4) and eliminates the need for opening the container to gain access to the desiccant.

The addition of a boss or other modification to the container may be necessary in order to effect a seal when it is intended to install the desiccant holder in a curved surface.

The covers for these holders may be provided with various breather valves in their centers. This eliminates the need for an extra hole in the container body.

Custom designed baskets frequently have been used as desiccant holders. These vary in size and configuration—depending on capacity required, location, and the availability of space within the container. These baskets may be made of perforated metal (Fig. 10-4), expanded metal (Figs. 10-5 and 10-6), or of wire (Fig. 10-7). Whichever type of desiccant holder is used, it should be located at the same end of the container as the breather valve and the humidity indicator to facilitate replacing the desiccant and allowing the containers to be stacked in storage with their ends against a wall to make optimum usage of the space available.

The desiccant should be located as far away from the humidity indicator as practical. Provision should be made for replacement of the desiccant, without opening the container, by providing a sealed opening through which the desiccant basket can be reached. A typical example of such an access door is shown in Fig. 10-8.

## 10-3 HUMIDITY INDICATORS

There are four general types of humidity indicators that have been used on missile containers:

a. Hexagon head humidity indicator plug

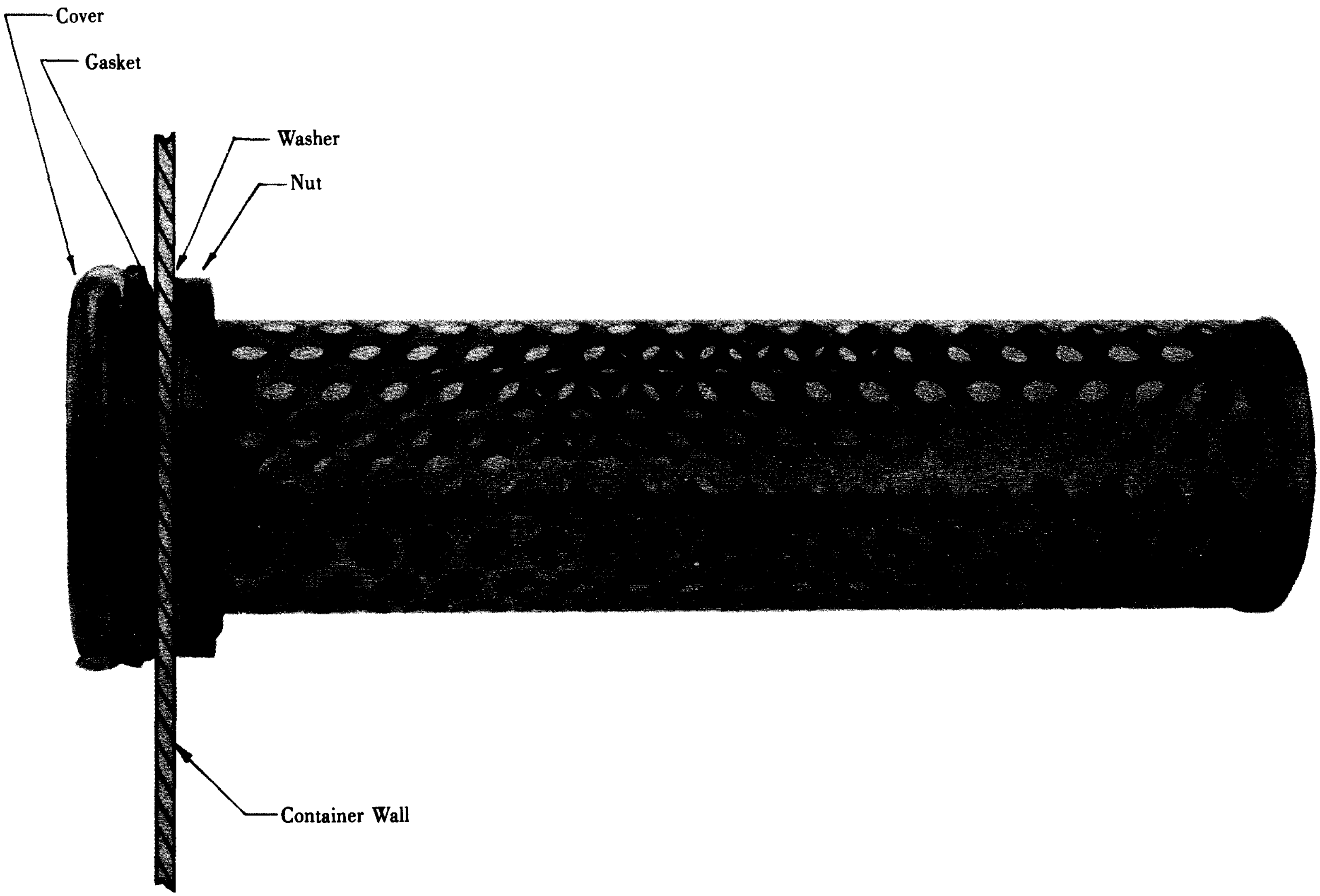



**Figure 10-4. Commercial-Type Desiccant Holder**

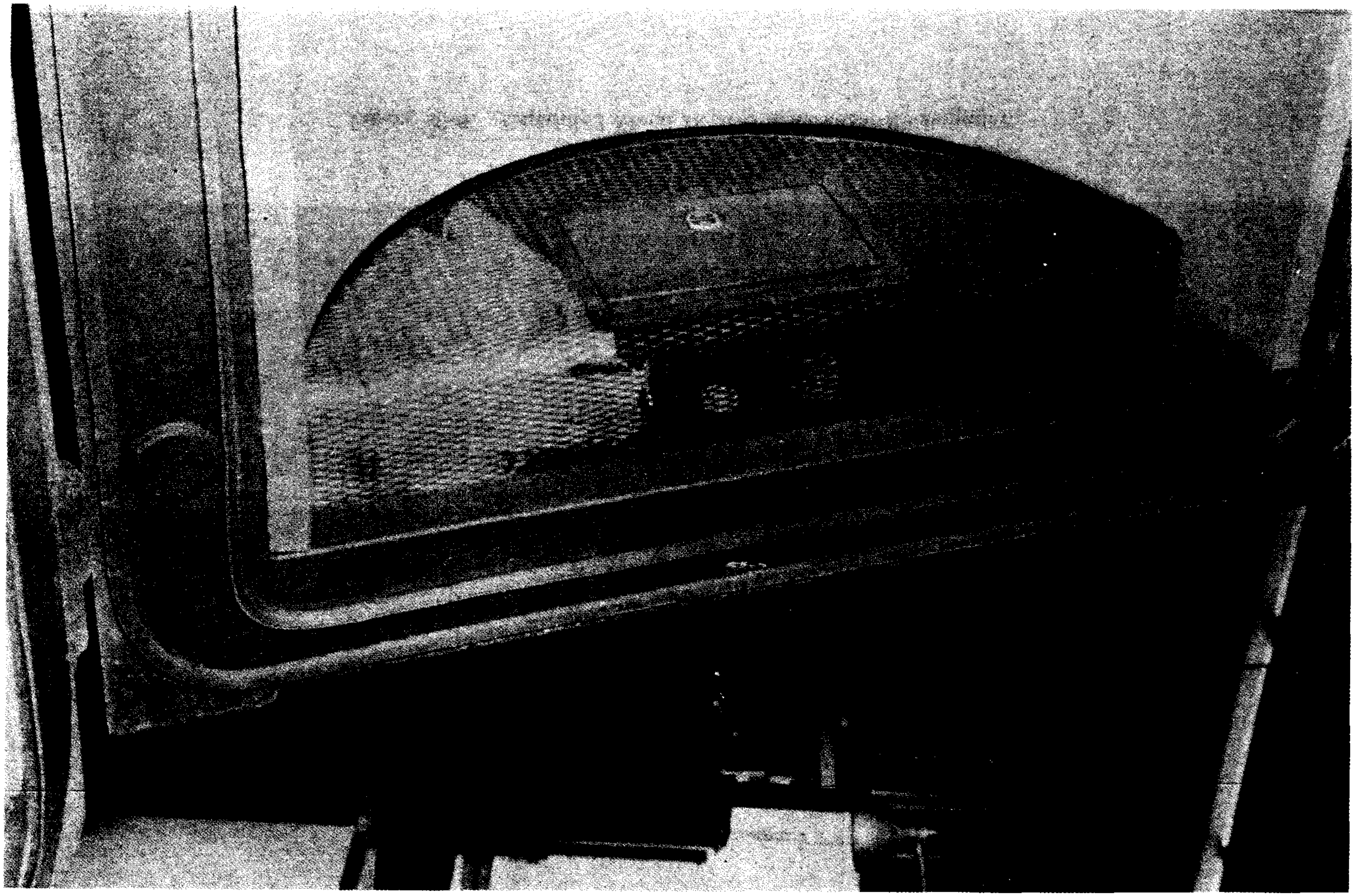


Figure 10-5. Expanded Metal Desiccant Basket—Semicircular

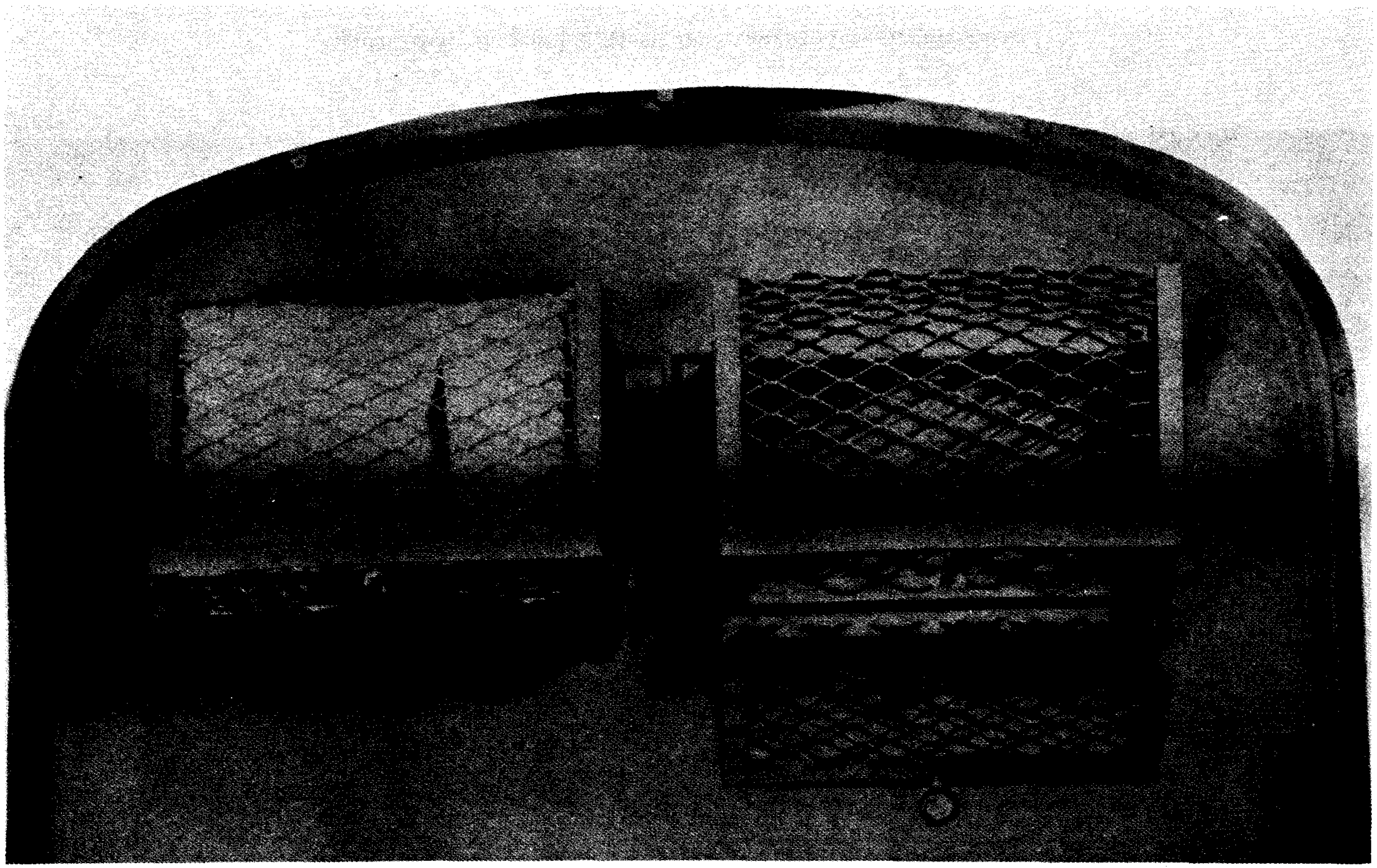


Figure 10-6. Expanded Metal Desiccant Baskets—Rectangular

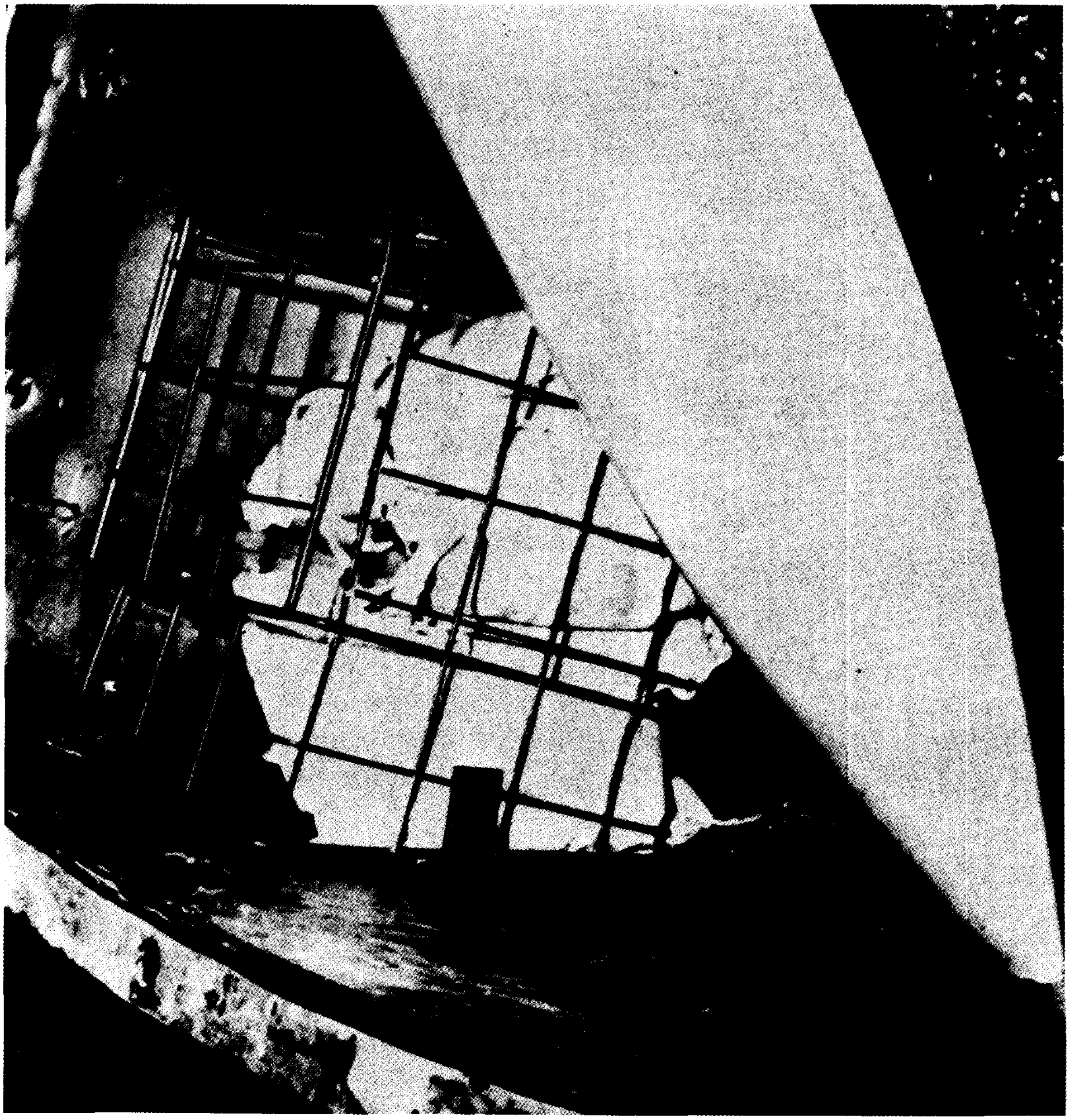


**Figure 10-7. Wire Desiccant Basket**

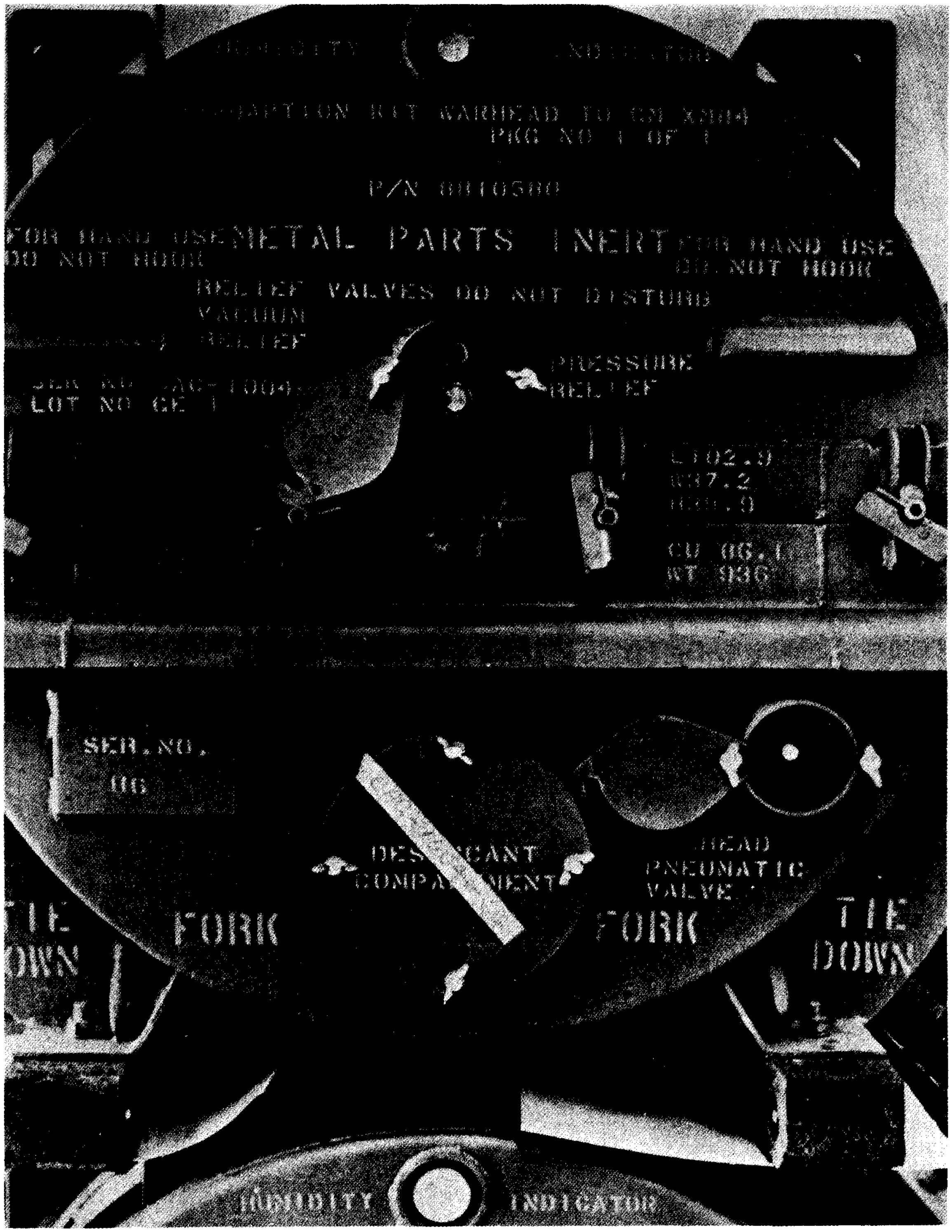



Figure 10-8. Desiccant Access Door

b. Round head humidity indicator plug
c. Card-type humidity indicator
d. Direct reading humidity indicator plug.

Each type is discussed in the paragraphs that follow.

### 10-3.1 HEXAGON HEAD HUMIDITY INDICATOR PLUG

The hexagon head humidity indicator plug is an externally mounted indicator consisting of a metal housing, a retaining gasket, and a washer and nut. A hole is drilled in the container, and the nut is welded over the hole on the inside of the container. The plug is then threaded into the nut with the gasket providing a seal (Fig. 10-9). The humidity card may be changed by using a standard adjustable or open-end wrench to remove the plug from the container. An internal hexagon wrench is then used to remove an internal nut from the plug so that the card may be removed. A variety of humidity cards is available for use in the hexagon head plug (Fig. 10-10). These indicators can be either "go-no-go" gages (Fig. 10-10(A)) or multiple range indicators (Figs. 10-(B),(C), and (D)).

The availability of such cards and the need of only standard tools for removal and replacement make the hexagon head indicator plug especially adaptable for use on missile containers.

### 10-3.2 ROUND HEAD HUMIDITY INDICATOR PLUG

The round head indicator plug is similar to the hexagon head plug except that the head is round and slotted (Fig. 10-11). This type, in addition to a standard adjustable or open-end wrench, requires a special tool to remove the plug from the container (Fig. 10-12). The tongue of the special tool fits into the slots, and a wrench is then used to turn the tool. Removal and changing of the humidity card is then accomplished in the same manner as in the hexagon head type. This type of indicator generally is used when the humidity indicator is to be placed in a well in the container wall for physical protection (Fig. 10-4). Need of a special tool for removal makes this type less desirable for use on containers than the hexagon type.

### 10-3.3 CARD-TYPE HUMIDITY INDICATOR

A card-type humidity indicator has also been used on missile containers (Fig. 10-13). This type consists of a paper or cardboard card with indicator spots impregnated on it. The card-type indicator is hung inside the container and requires a window in order to be read without opening the container. When used in pressurized containers, this window requires a seal.

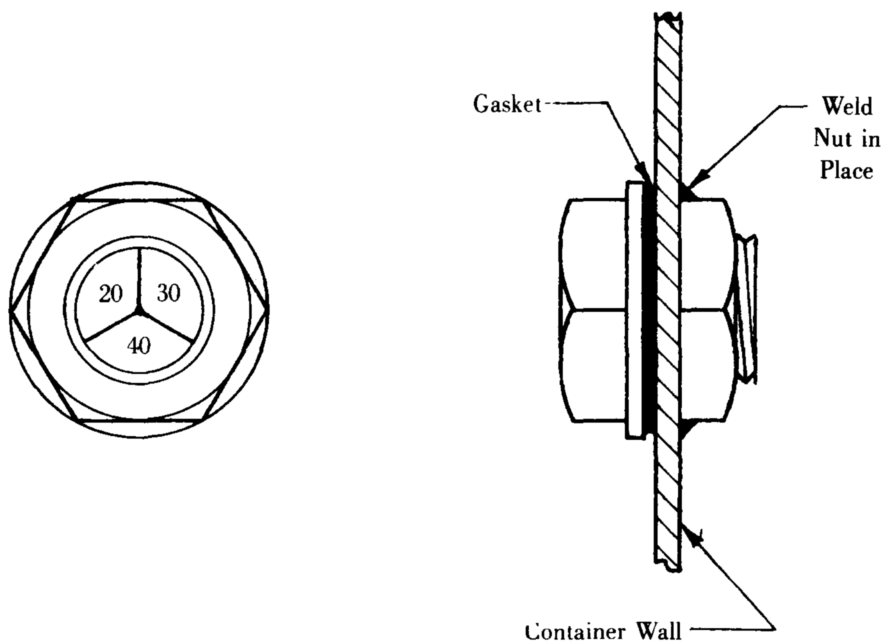



**Figure 10-9. Hexagon Head Humidity Indicator Plug**

In some instances, a light source would also be necessary to read the indicator. These requirements make the card-type indicator the least desirable for use in missile containers.

### 10-3.4 DIRECT READING HUMIDITY INDICATOR PLUG

A direct reading humidity indicator plug (Fig. 10-14) is also available for use on missile containers. It incorporates the use of a sensitive biplastic element which bends in response to changes in relative humidity (RH). As the RH changes, the end of the element moves across a scale printed on the face of the indicator giving a direct RH reading. The scale gives a continuous reading over a range of RH's within a temperature range of 32° to 140°F. The readings are accurate to within ±5%, and no temperature correction factor is needed. This scale can be calibrated to cover any range of RH desired. The response time of the element is short, requiring only minutes to register a change in RH. Instructions for represervation when a certain RH level is exceeded can be printed on the face of the indicator surrounding the dial or on the container itself. This indicator plug is a hexagon head type and is mounted in the same manner as the color change hexagon head type. Complete removal and changing of the element requires only a standard adjustable or open-end hexagon wrench.

### 10-3.5 RECOMMENDED TYPES AND LOCATIONS

It is recommended that in order to standardize the use of humidity indicators, the general requirements of MIL-I-26860 and MS20003 be satisfied. MIL-I-26860 requires a plug type indicator which can be removed and replaced using only common hand tools. The hexagon head type best meets this

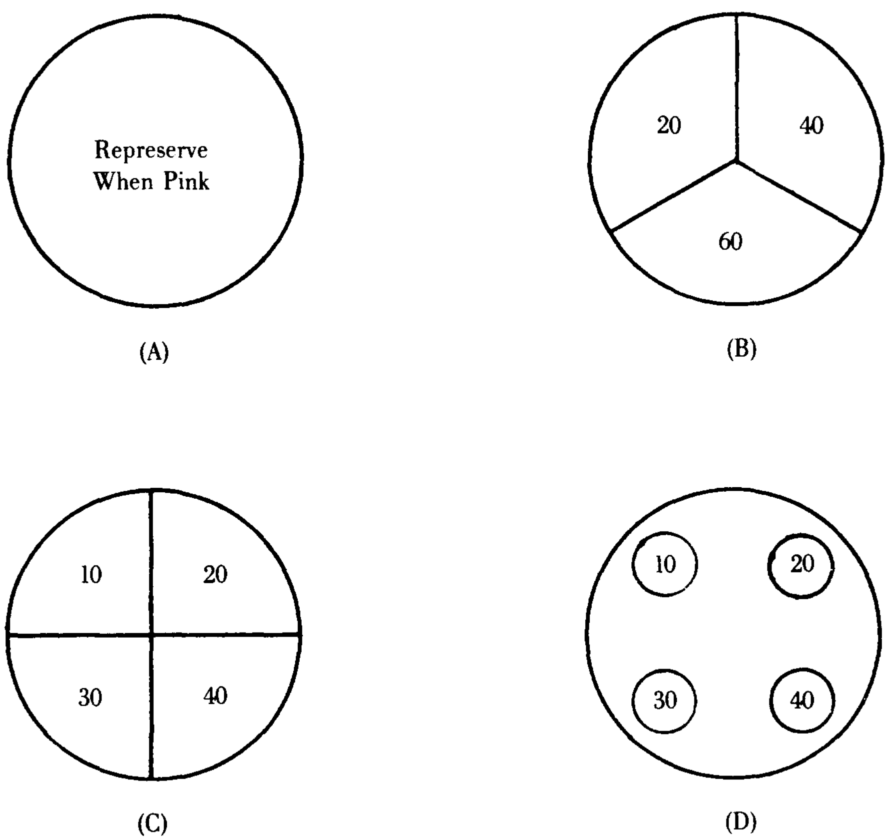



**Figure 10-10. Cards for Use in Plug-Type Humidity Indicators (Multiple Range Cards Shown in (B), (C), and (D).)**

requirement, and the availability of multiple range cards or direct reading elements makes the hexagon head type adaptable to any RH requirements. Since the round head type requires a special tool for removal, it is recommended that the hexagon head plug be used as the standard humidity indicator. Choice of card or direct reading type depends on the individual requirements of the item being packaged.

The humidity indicator and desiccant basket should be located at the same end of the container—but as far apart as possible—in order to facilitate removal and servicing. Studies have shown that the indicator will not give erroneous results in this position since the vapor pressure of the air is eventually equalized throughout the container causing the RH to be constant throughout the container.

Typical humidity indicator plug installations are shown in Figs. 10-15 through 10-17.

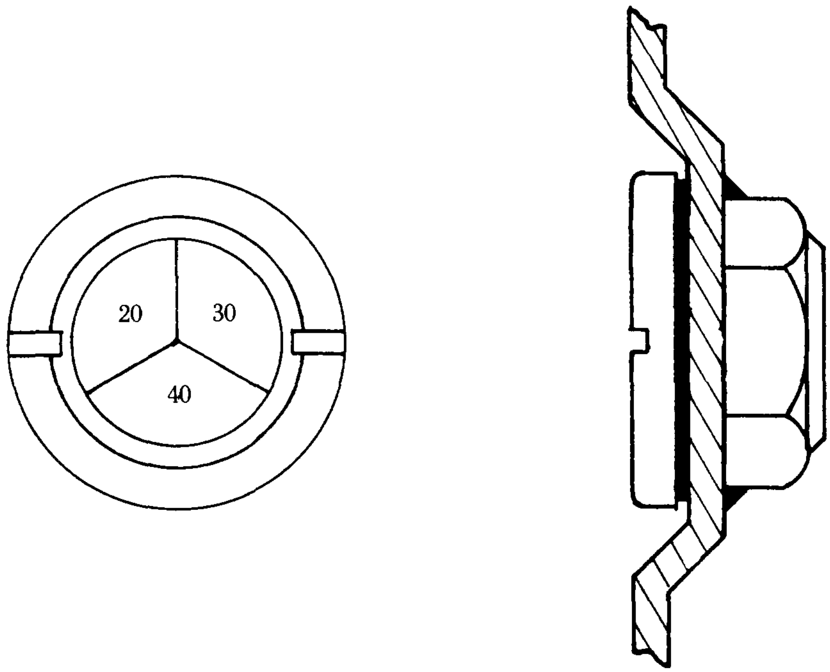



**Figure 10-11. Slotted Round Head Humidity Indicator Plug**

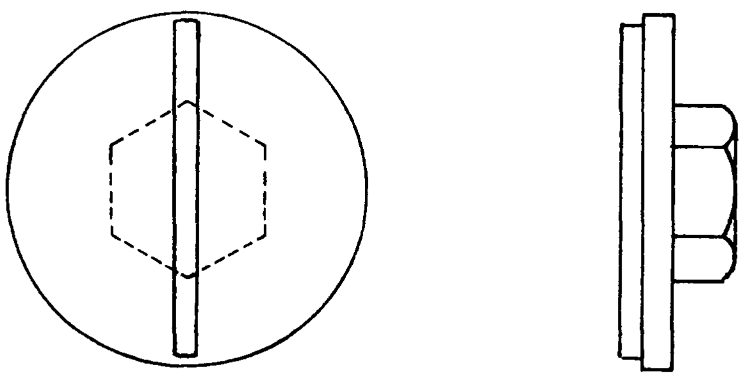


**Figure 10-12. Special Tool for Installation and Removal of Slotted Round Head Humidity Indicator Plug**

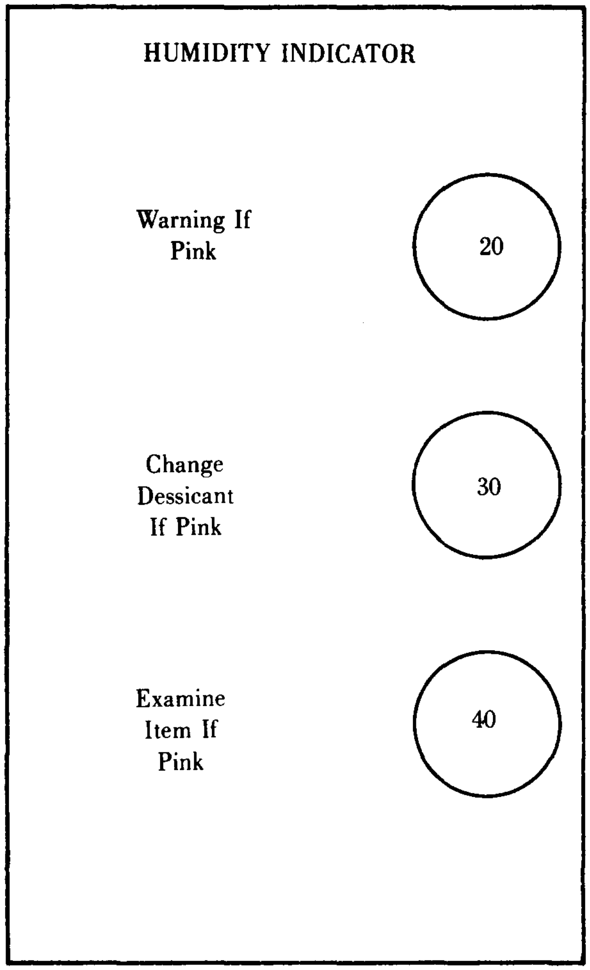



Figure 10-13. Card-Type Humidity Indicator (Multiple Range)

**Figure 10-14. Direct Reading Humidity Indicator Plug**

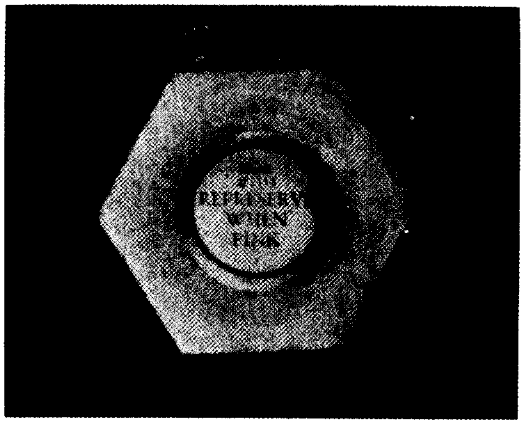


**Figure 10-15. Hexagon Head Humidity Indicator Plug Installation**

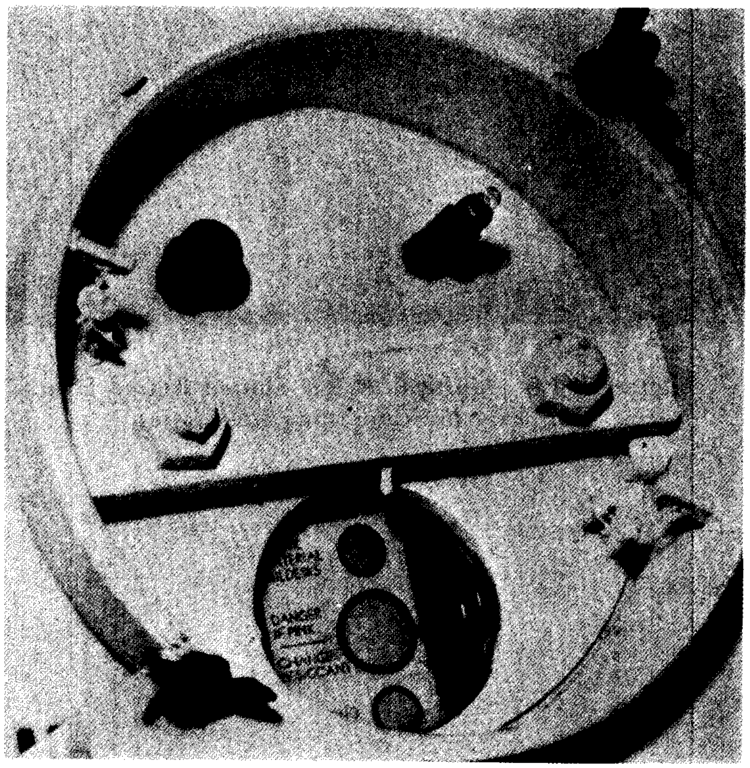


Figure 10-16. Card-Type Humidity Indicator Installation

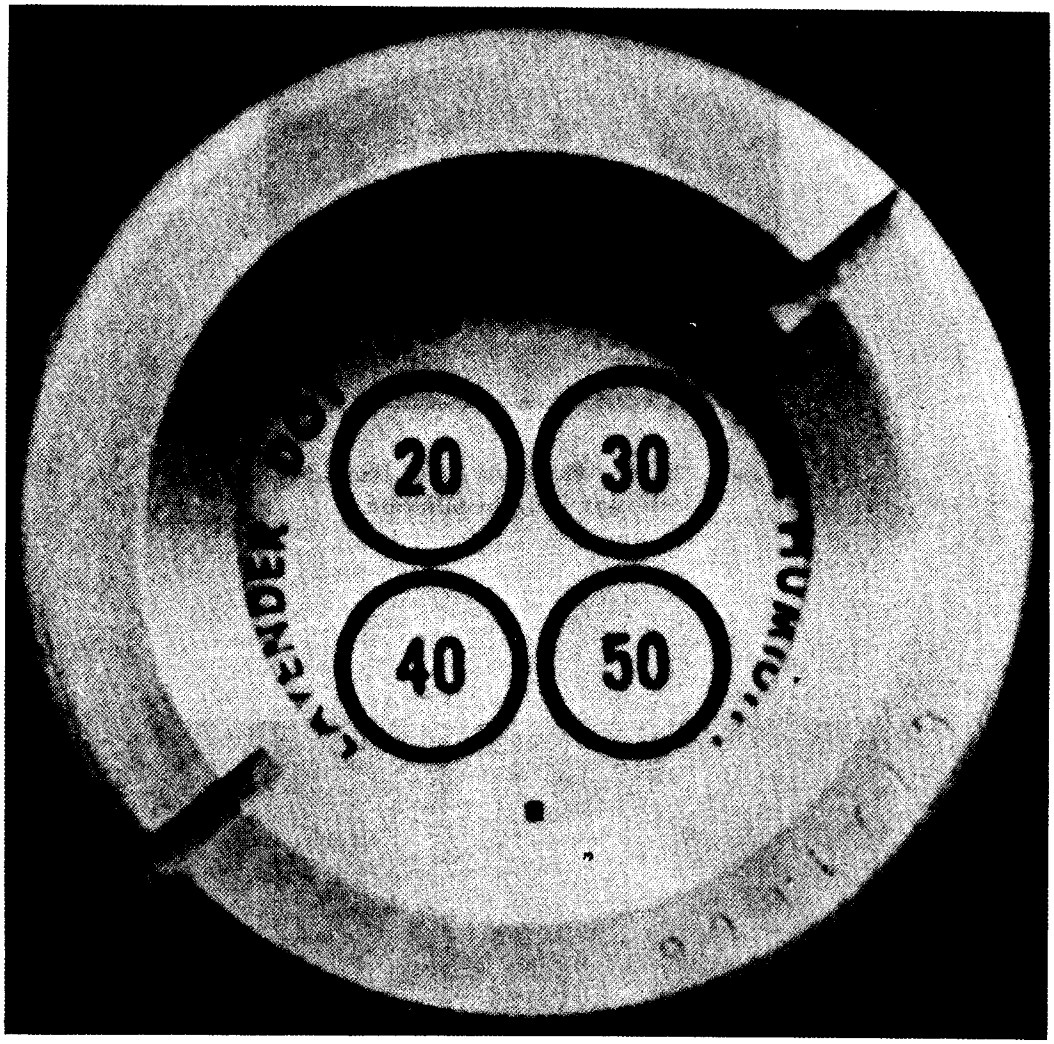



Figure 10-17. Multiple Range Slotted Round Head Humidity Indicator Plug Installation

# CHAPTER 11
# FASTENERS AND SEALING

*Advantages/disadvantages of various types of fasteners and gasket materials are presented.*

## 11-1 COVER FASTENERS

### 11-1.1 GENERAL

Fasteners on missile containers serve to secure covers, provide sufficient pressure on gaskets to effect a seal, and to secure auxiliary devices such as access holes, log receptacles, and tool boxes. The number and type of fasteners should be commensurate with requirements of stress, bonding, sealing, etc. Cover fasteners preferably should be of the quick-acting, over center type. In the closed position, the fasteners should project as little as possible and should be completely within the container profile. On top-opening containers, the fasteners should be protected from handling damage by external flanges above and below the fasteners, forming a channel within which the fasteners are located (see Fig. 11-1). To permit the use of quick-acting fasteners on top-opening containers, the sealing flanges on the container shell should be turned inward (see Fig. 11-1). On end-opening containers which open from both ends, quick-acting fasteners should be used only on the end from which the missile is removed. Less expensive, but equally effective, fasteners (normally bolts) should be used on the end which is used less frequently.

In choosing a cover fastener for use on a missile container, particular attention should be given to speed and ease of operation and to container sealing requirements. Fasteners must meet the following basic requirements:

a. Operable with arctic mittens unless definitely established that such conditions will not be encountered

b. Rugged enough to absorb impact loads encountered in handling and in the removal of ice formations

c. Capable of repeated use

d. Operable by unskilled personnel

e. No loose components after unlatching.

The following characteristics, though not essential, are desirable on container fasteners:

a. Adjustable fastening tension

b. Lock in closed position

c. Do not employ springs which are susceptible to failure due to ice formations or shock imputs

d. Easily replaceable by depot personnel

e. Recessed or protected by projecting channels if fasteners are susceptible to damage

f. Commercially available where possible.

The fasteners used on missile containers can be conveniently classified as screw type, draw-pull type, or slide-action type. Each type is discussed.

### 11-1.2 TYPES OF FASTENERS

#### 11-1.2.1 Screw-Type Fasteners

The most suitable screw-type fastener is the T-head bolt (Fig. 11-2). This type permits unfastening without removal of the nut from the bolt, thus preventing loose parts from being lost. It also has the advantage of allowing individual tightening without prior adjustment. T-head bolts permit faster cover removal than regular nuts and bolts, but if a large number of T-bolts are used, the total unlatching and/or reassembly time could become excessive.

#### 11-1.2.2 Draw-Pull-Type Fasteners

Many fasteners employ different actuating principles yet fall under the general heading of draw-pull. They are quick acting, over center-type fasteners which contain no loose parts when opened. This eliminates the possibility of losing part of the fastener when the container is open. Two types of commercially available draw-pull fasteners which have been used on missile containers are shown in Fig. 11-3. Custom designed fasteners should not be used since they are more expensive than the standard commercially available fasteners. As can be seen, draw-pull fasteners can usually be obtained to meet any closure requirements. When used on top-opening containers, the fasteners should be strong enough to permit the container to be lifted from above by means of the cover. Although this is *not* the ideal way to lift a container, it is sometimes necessary when a forklift truck cannot be used and when adjacent containers allow no space to reach the bottom of the container to be lifted.

Another type of draw-pull fastener is the compression spring fastener shown in Fig. 11-4. These fas-

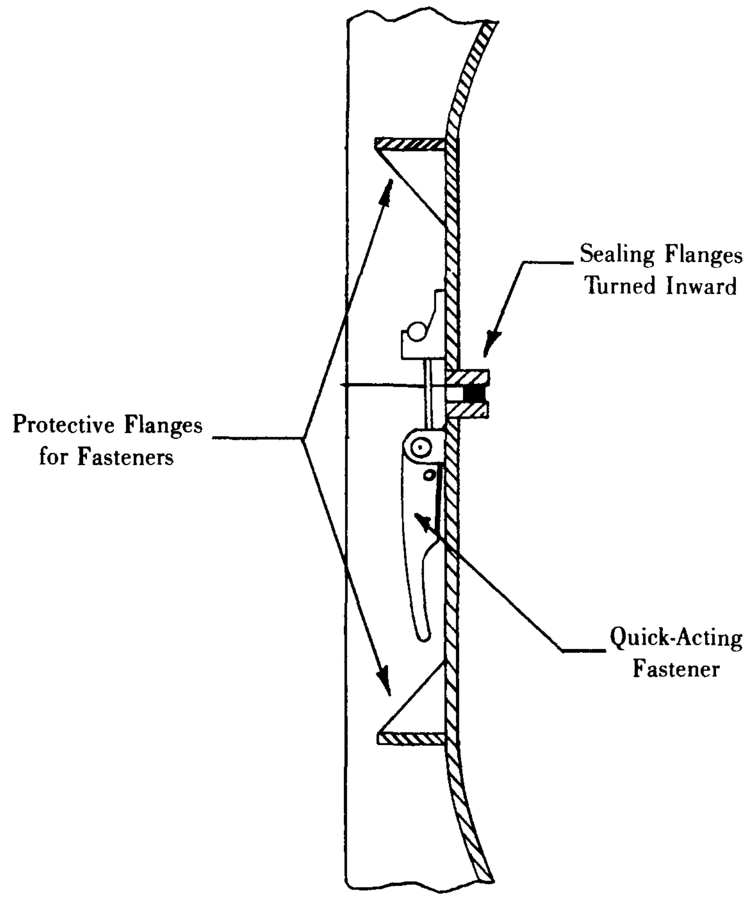



**Figure 11-1. Container-Fastener Configuration**

teners employ one or more springs to provide a given fastening tension. They are used to insure a constant closure force and also when accurate installation spacing is impractical. This fastener should not be used on containers stored outdoors due to the possibility of corrosion and, during the winter, ice formations which will make the latch difficult to operate.

#### 11-1.2.3 Slide-Action-Type Fasteners

This type of fastener employs a horizontal bolt-like member usually attached to or enclosed within a housing (Fig. 11-5). The bolt-like member can be moved across the edge of the enclosure to engage within a keeper which is usually mounted on the frame or body of the container. This type latch is easily and quickly opened and closed and is ideally suited for use on containers that do not require a seal.

## 11-2 SEALS

### 11-2.1 GENERAL

Gaskets on missile containers function to provide environmental seals to prevent the entrance of undesirable foreign matter. Gaskets also serve to seal auxiliary equipment on the container body and often to provide shielding from electromagnetic interference (EMI). When designing a joint and choosing a gasket, the following areas should be considered:

a. Pressure required to effect a seal under the anticipated environmental conditions
b. Required joint surface finish
c. Gasket material
d. Gasket compressibility or noncompressibility
e. Standard gasket shapes
f. Ease of field replacement

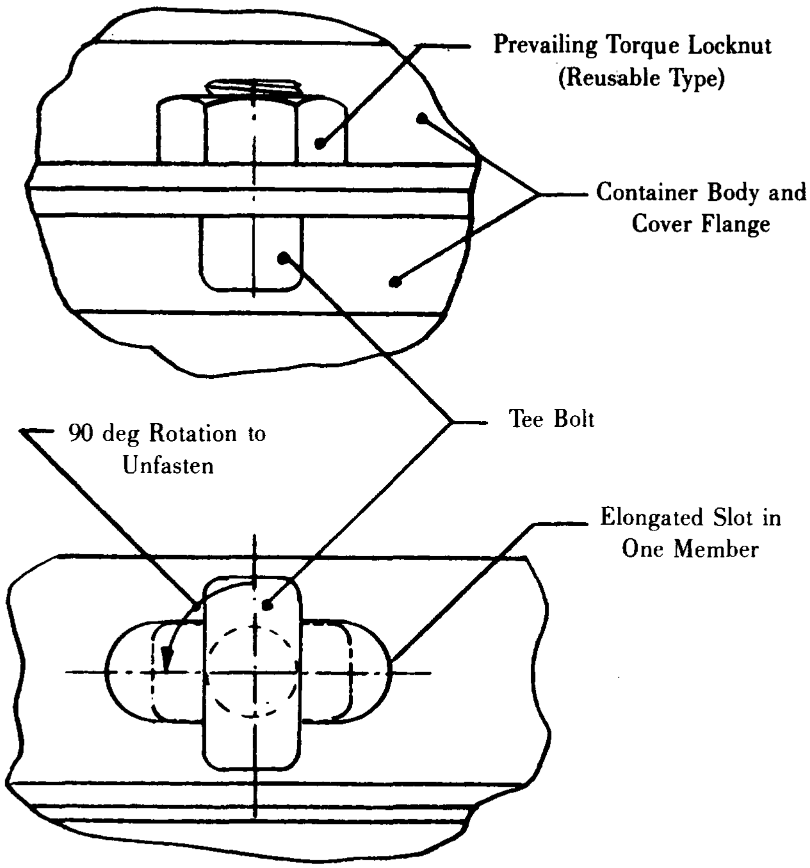



**Figure 11-2. T-Bolt**

g. Compounds available for joining gasket materials to metal

h. Compounds available to prevent gaskets from adhering to metal

i. EMI shielding requirements (see Chapter 13)

j. Cost.

Since new plastic/polymeric materials suitable for gaskets are constantly being developed, the Plastics Technical Evaluation Center (PLASTEC), US Army Armament Research and Development Command, should be consulted in order to select the best material for the particular application. However, as an initial guide to the selection of gasket materials, refer to Tables 15-9, -10, -11, -13, and -14.

## 11-2.2 JOINT DESIGN

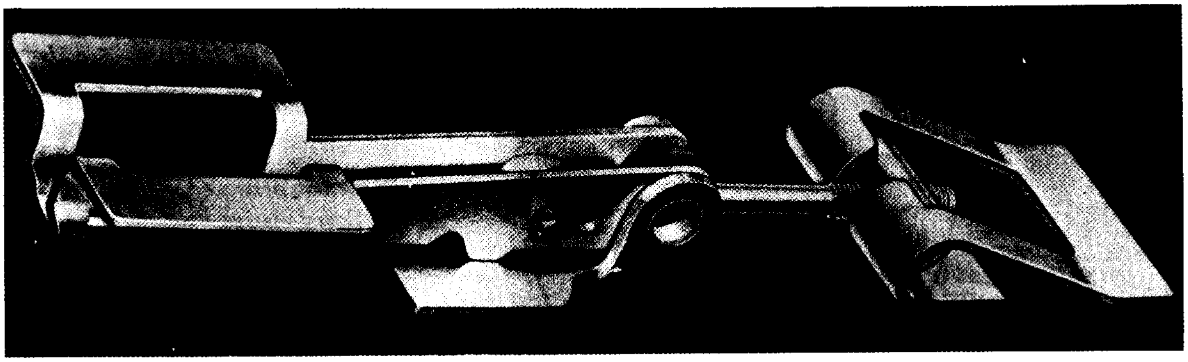
Sealed joints on containers should be designed so that the cover and the body of the container meet in positive contact when the gasket is compressed a predetermined amount sufficient to effect a seal. When a compressible gasket such as rubber is used, the joint must be designed to allow for the side expansion of the gasket. A variety of joint designs limited only by the ingenuity of the designer can be employed; Fig. 11-6(A) illustrates the two possibilities.

As shown in Fig. 11-6(A), a bead or spacer can be provided along the closure flange of the container. Before compression, the gasket extends above the bead. Fastening the cover compresses the gasket until the cover closure flange contacts the bead. Additional compression would not be possible. A solution to joint design allowing additional compression is shown in Fig. 11-6(B).

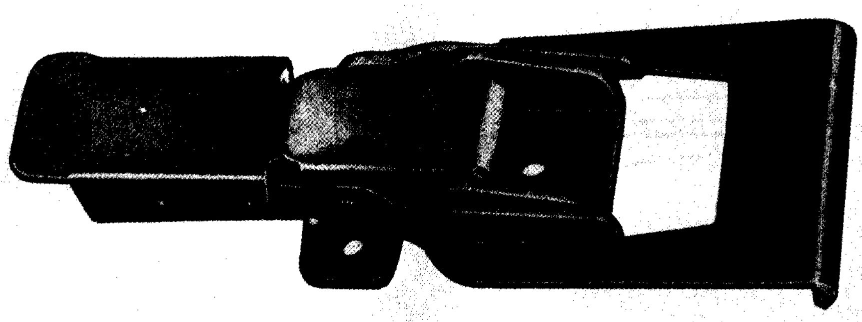
## 11-2.3 FLANGES

### 11-2.3.1 Pressure Considerations

In designing a joint, the sealing obtained can be related to flange pressure, and the critical condition in achieving a seal can be expressed in terms of the initial unit load on the gasket. The least unit gasket



(A)



(B)

**Figure 11-3. Draw-Pull Fasteners**

load required to achieve a seal is called the minimum sealing stress. This is the key factor in designing a gasket. It has been found that with a rubber gasket and a zero internal pressure, a seal can be created with a 50-psi flange pressure. However, even though a seal can be created at a low loading condition, a flange pressure of at least 200 psi is required to maintain a seal after it is created—regardless of the type of gasket—assuming a nonporous or impervious material is used. Creating a seal is not sufficient; the seal must be maintained under operating conditions which include vibration, shock, and temperature variations. To prevent these factors from opening a seal, initial flange pressures above those for creating the seal are therefore required.

**11-2.3.2 Surface Roughness Considerations**

Flange surface roughness is of no consequence if minimum sealing stresses are achieved. With flange pressures of 200 psi or higher a surface roughness as high as 250 $\mu$in. can be tolerated using rubber composition gaskets. Generally the thinnest gasket that will seal a joint should be used. If the minimum sealing stress is achieved, a 10 to 20% compression in

a rubber gasket is adequate for a gas seal. Since there is considerable leeway in the choice of gasket thickness, whenever possible, a standard commercial thickness and shape should be specified in the interest of economy.

## 11-3 GASKET MATERIALS

Gaskets used today are made of nonhygroscopic materials; hence wicking is not a problem. However, in order for the gasket to function as intended, it must be cut in a manner which will allow it to extend beyond the outer periphery of the flanged area. This will eliminate moisture traps which generally act as an origin for the formation of oxides which then propagate along the flange surface into the area that is being sealed.

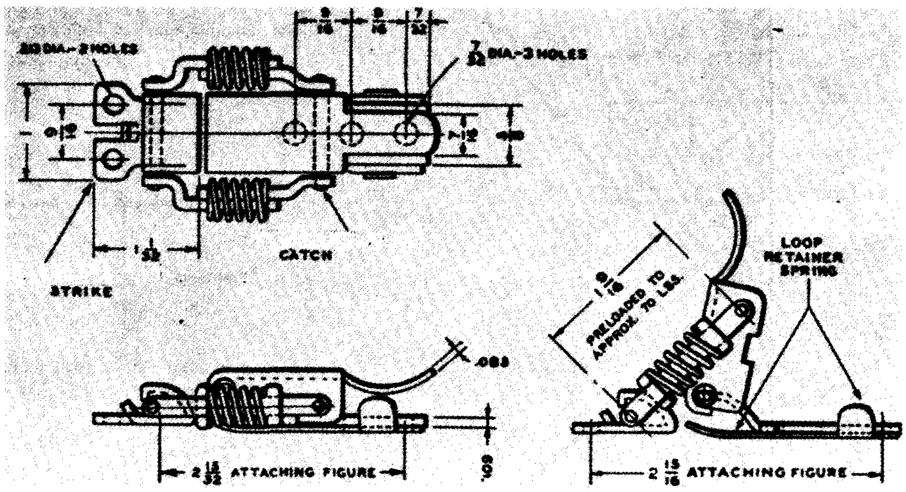



Figure 11-4. Compression Spring Fastener

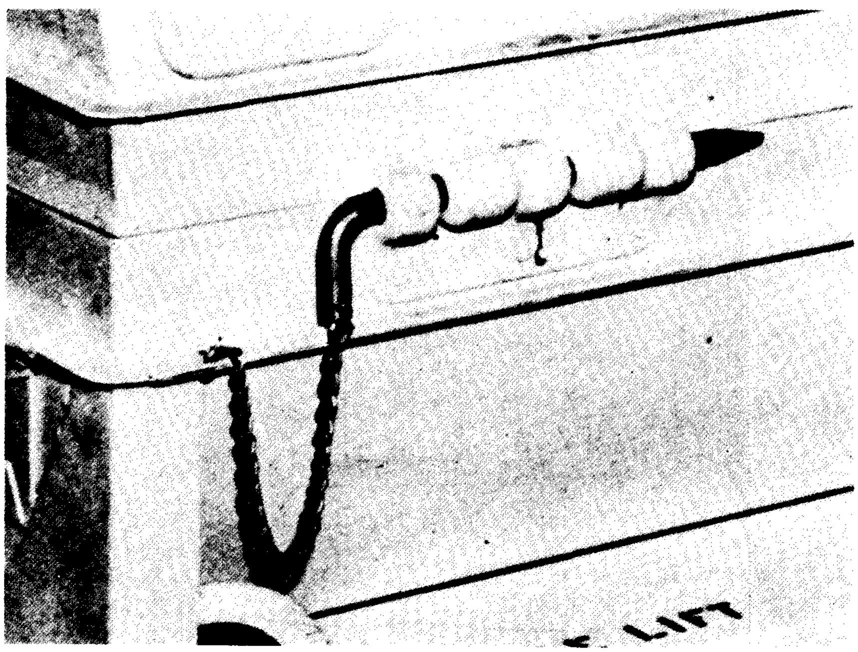
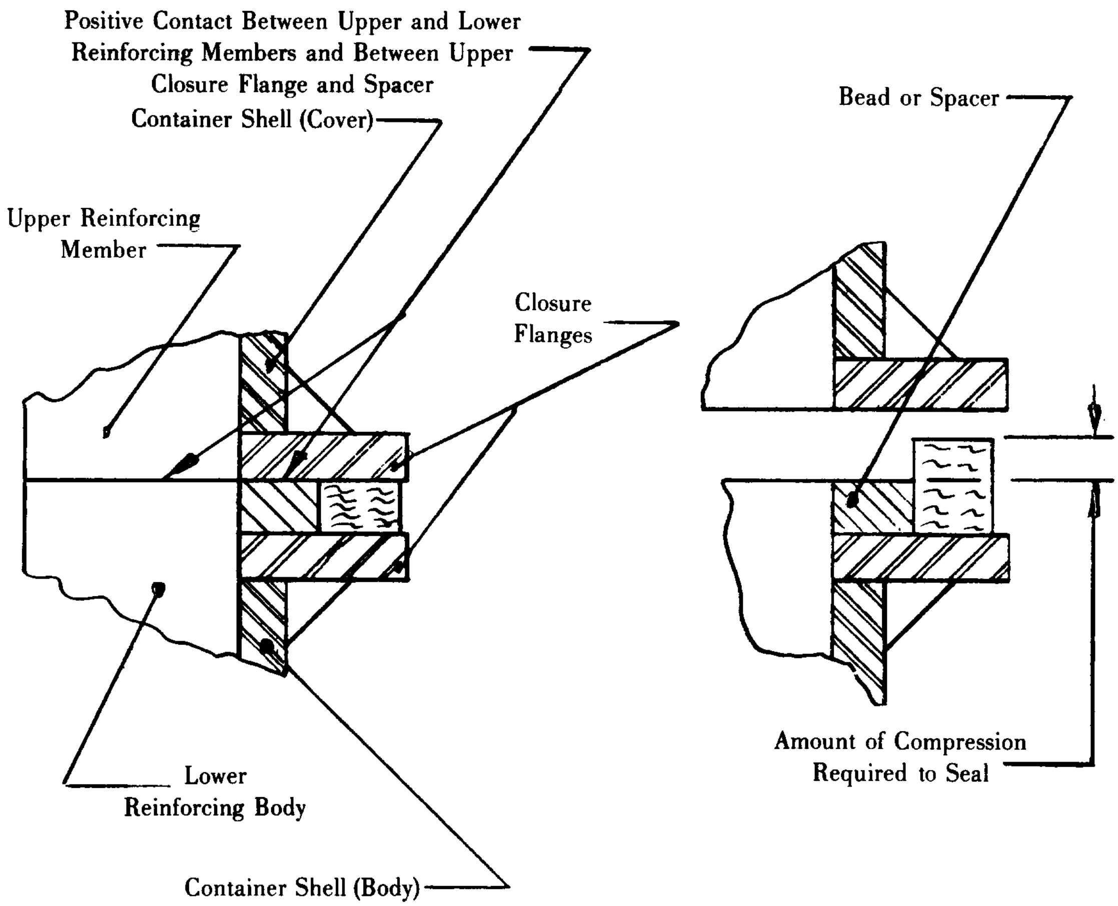
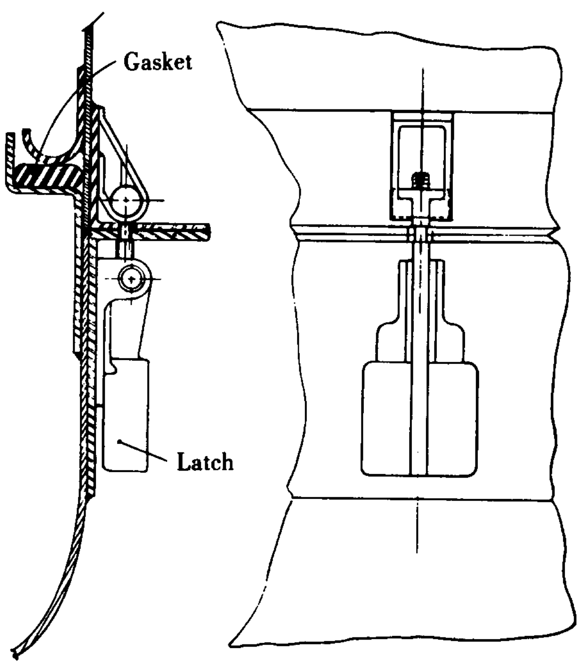


Figure 11-5. Slide-Action Fastener




(A) Restricted Gasket Compression




(B) Increased Gasket Compression

**Figure 11-6. Container Joint Designs**

# CHAPTER 12
# TEMPERATURE CONTROLLED CONTAINERS

*The need for temperature controls is discussed, and the methods of achieving temperature control are presented.*

## 12-1 GENERAL

More of today's equipment is becoming temperature-sensitive. This equipment may require precise temperature control for proper functioning or may only require such control to guard against damaging temperatures. Items such as gyros and guidance systems must be kept at precise temperature levels with no more than one or two degrees deviation from their required temperature. This precise temperature control often is required from the time the item is manufactured until and during its use. The majority of temperature-sensitive items, however, will only require such temperature control to escape damaging temperatures. For example, a rocket motor must not be allowed to get so hot as to self-ignite, or so cold as to weaken the bond between the propellant and the outer shell.

Some items do not require temperature control as such but are only sensitive to temperature shock (a fast rate of temperature change). Temperature shock can be effectively controlled by insulation only, but temperature control is a great deal more complicated.

Methods of controlling temperature can be by either auxiliary power, batteries, thermophormic materials, or any combination of these. Each method is discussed.

## 12-2 AUXILIARY POWER

Auxiliary power used for controlling container temperatures may be obtained either from a plug-in source or from a portable power unit. These methods, however, lack the desired flexibility and require constant monitoring.

Carriers cannot always be relied on to supply power for these containers. Even when carriers are equipped with plug-in facilities, they are not necessarily always of the same voltage. A container designed to operate on one particular voltage may find itself in a carrier equipped with a different voltage.

A portable power unit often accompanies a container requiring auxiliary power and precludes the use of requiring the carrier to supply power. Portable power units also allow these containers to be stored at locations where there is no power available. The disadvantages of portable power units are: (1) they represent a fire hazard, (2) they require maintenance and fuel, (3) they are usually large and bulky, and (4) they must usually be manned at all times.

In order to achieve the flexibility of a portable power unit without all of its disadvantages, self-contained power sources such as batteries or self-contained heat sources such as thermophormic materials may be used in conjunction with auxiliary plug-in power. These self-contained power sources and heat sources will allow the container to be self-sufficient for a limited amount of time when required.

## 12-3 BATTERIES

Batteries have the advantage of being lighter and smaller than portable power units, are quiet, and require no in-transit support. Some of the disadvantages of lead-acid batteries are:

a. They use corrosive acids.

b. They are prone to deterioration from charging and discharging.

c. They produce an explosive mixture of hydrogen and oxygen when they are used.

Another disadvantage of batteries is that their efficiency decreases as the temperature decreases. Unfortunately, when batteries are used for temperature stabilization in containers under cold environmental conditions, power is least available at a time when power is needed most. Elevated temperatures will accelerate battery discharge.

The vented sintered plate, nickel-cadmium (Ni-Cad) battery overcomes many of the disadvantages of the lead-acid battery; it is, however, relatively expensive. Advantages of the Ni-Cad battery follow:

a. Very little gassing occurs on charging, except when overcharged, and none on discharge. Consequently, little water is lost.

b. The rate of discharge is very low. Thus the battery may be left standing on open circuit for peri-

ods up to a year and still retain as much as 70% of its original charge.

c. It will accept a charge at a temperature as low as -40°F by virtue of self-heating. At temperatures below -40°F, however, the electrolyte forms a slush which slows down the chemical reactions.

Two containers using battery power are shown in Figs. 12-1 and 12-2. Although batteries are lighter and smaller than portable power units, they still use a large amount of space as shown in these figures.

## 12-4 THERMOPHORMIC MATERIALS

Thermophormic materials store heat by heat of transition or heat of fusion. These materials were developed to maintain fixed temperatures in containers during shipment with temperature tolerances as required. They have the ability to store the largest possible amount of heat in the smallest volume and weight, at well-defined temperatures, i.e., the melting points of the material. On a pound for pound, volume for volume, or dollar for dollar comparison, heat may be stored more cheaply and efficiently in a thermal* battery than in an electric storage battery. Two containers using thermal batteries are shown in Figs. 12-3 and 12-4.

A thermal battery container consists of essentially four elements: structural container, insulation, item, and thermophormic material. These thermophormic materials usually are permanently encased in sealed containers to avoid any loss or contamination. An electric heater is placed in thermal contact with the thermophormic material so that the material can be fully charged prior to shipment and during storage. Fig. 12-5 shows a schematic drawing of a typical container employing a thermal battery.

To better grasp the theory of thermophormic materials, a theoretical example is given. For an ideal case, assume that an item will be damaged if it is exposed to a temperature below 25° F. If the shipping container for this item was expected to be exposed to an ambient temperature of -40° F, then a very good thermophormic material would be water. By having the water enclosed in its own cannister and being near the temperature-sensitive item, it will give up its stored heat as it is solidifying or cooling.

If the water (or heat exchanger as it should be called) is heated to 92° F and then subjected to a cold environment below 32° F, each pound of water will give up one Btu for each degree Fahrenheit drop in temperature until 32° F is reached. At this temperature the water solidifies giving off further heat without any further decrease in temperature. It is at this plateau that the term "heat of fusion" is applied. For water, this amounts to 144 Btu's/lb. Theoretically, each pound of water at 92° F has given up 204 Btu's (60 Btu's for the temperature drop from 92° F to 32° F plus 144 Btu's heat of fusion) and the temperature of the water has not gone below 32° F. This is shown graphically in Fig. 12-6. Water, when solidifying, has a large expansion rate which may prevent its use since it may burst the closed system. Formulated thermophormic materials have very low expansion rates when solidifying.

By calculating the Btu per hour heat loss through the insulating material, the length of time the item will be protected can easily be determined. One major advantage of using this type of temperature control is that the thermophormic materials may be recharged by simply melting the material and elevating the temperature.

When selecting a material for use as a heat exchanger, the following factors should be considered:

a. What is the minimum temperature that must be maintained? The heat-storing material should have a freezing point above the minimum required temperature.

b. Is the chemical composition of the heat exchanger material harmful to the container?

c. Is the material used for the heat exchanger toxic or harmful to humans?

d. Is the expansion and contraction of this material too great?

e. Will the continuous cycle of melting and freezing of this material change its chemistry? Is it possible for some materials to change their composition after repeated cycling and then not solidify at the required temperature?

f. Will the heat exchanger give up its heat rapidly enough to maintain the desired temperature level?

g. Does supercooling take place with this material? This is a characteristic of pure liquids that are motionless. The temperature may drop 20 deg F or more below the freezing point of the liquid before solidification takes place. Once solidification starts, the temperature of the liquid will jump almost immediately back to the freezing temperature. It is easy to see, therefore, that the temperature may have dropped below the damaging level before the heat of

* The use of "thermal battery" in this context is not to be confused with the thermal battery which is made instantly active by the ignition of a pyrotechnic charge which liquifies an electrolyte.

fusion is released. Supercooling sometimes can be prevented by adding certain impurities to the liquid or by having some mechanical means of tapping or disturbing the heat exchanger to start crystallization.

## 12-5 INTERNAL HEATERS

The conventional and probably the most widely used method of controlling temperature in a container has been by internal heaters. These heaters readily convert electric energy directly into heat energy by either electrically heated blankets which surround the item or by electric space heaters (Fig. 12-7).

The electrically heated blanket consists of heating elements sandwiched between plies of the blanket material, usually just under the surface layer. These blankets usually consist of two halves, the top half and the bottom half. The larger covers are divided into various sections which are individuallv thermostatically controlled. This provides a more even temperature distribution over the item.

Electric space heaters incorporate a thermostatically controlled heating element and are usually of a forced, circulation type; i.e., they incorporate a fan for the circulation of air. In the larger containers, two or more fans usually are incorporated to maintain a more even temperature distribution.

The control panel and warning system for temperature-controlled containers range from extreme simplicity to ones that are so complicated that training programs are required to be able to understand them. The degree of complication required for these control panels depends on the end usage and what information is required. A continuous temperature monitoring system may be required or desirable at times or a simpler method that indicates when the temperature has dropped below the critical level may be adequate. There should also be some means

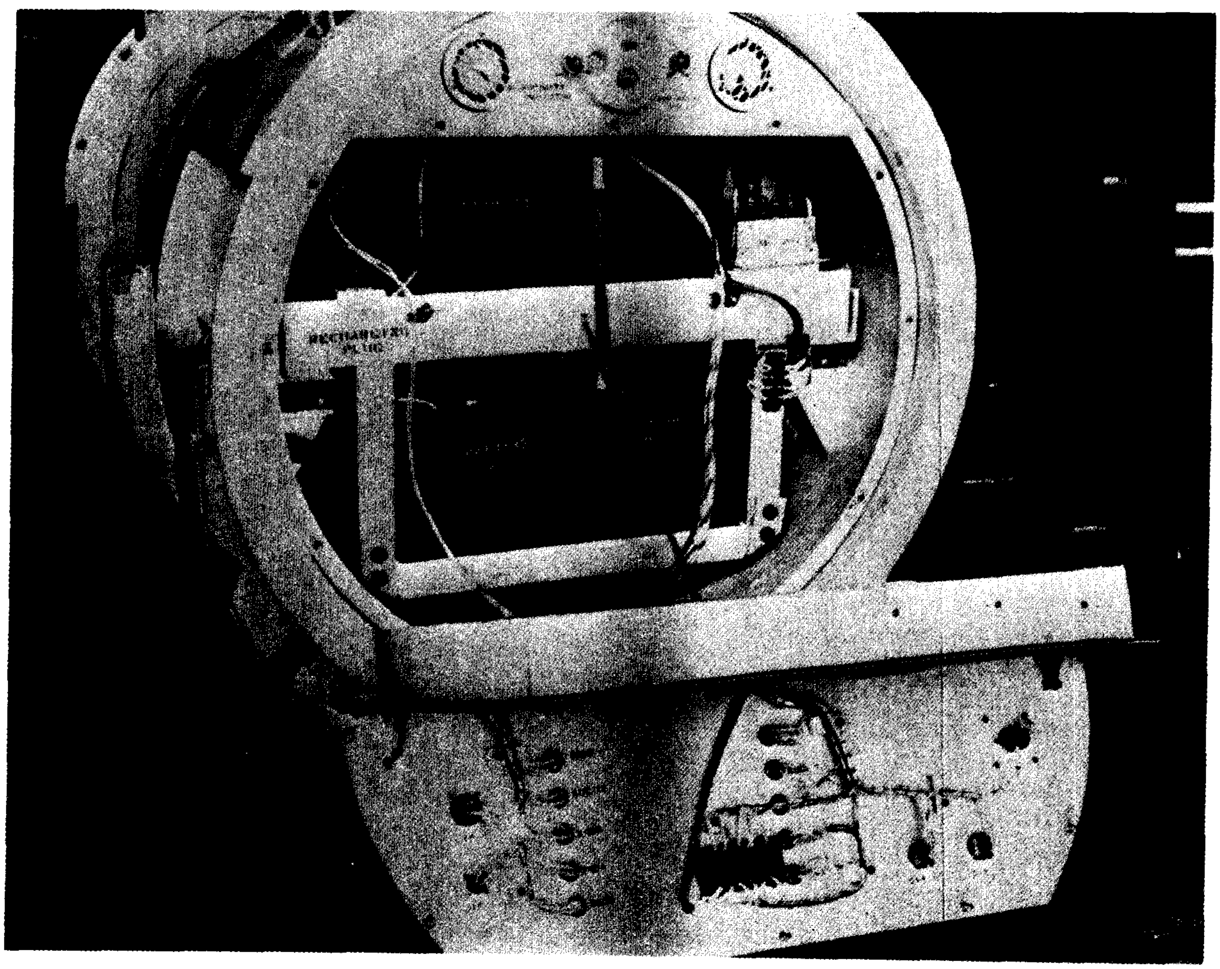


**Figure 12-1. Internal Battery Power Source for POLARIS Guidance System**

of indicating when the container is fully charged and ready for shipment. It must be remembered, however, that the distribution of most of today's equipment is worldwide and that many different types of personnel will be handling the container. The design, therefore, should be kept as simple and foolproof as possible.

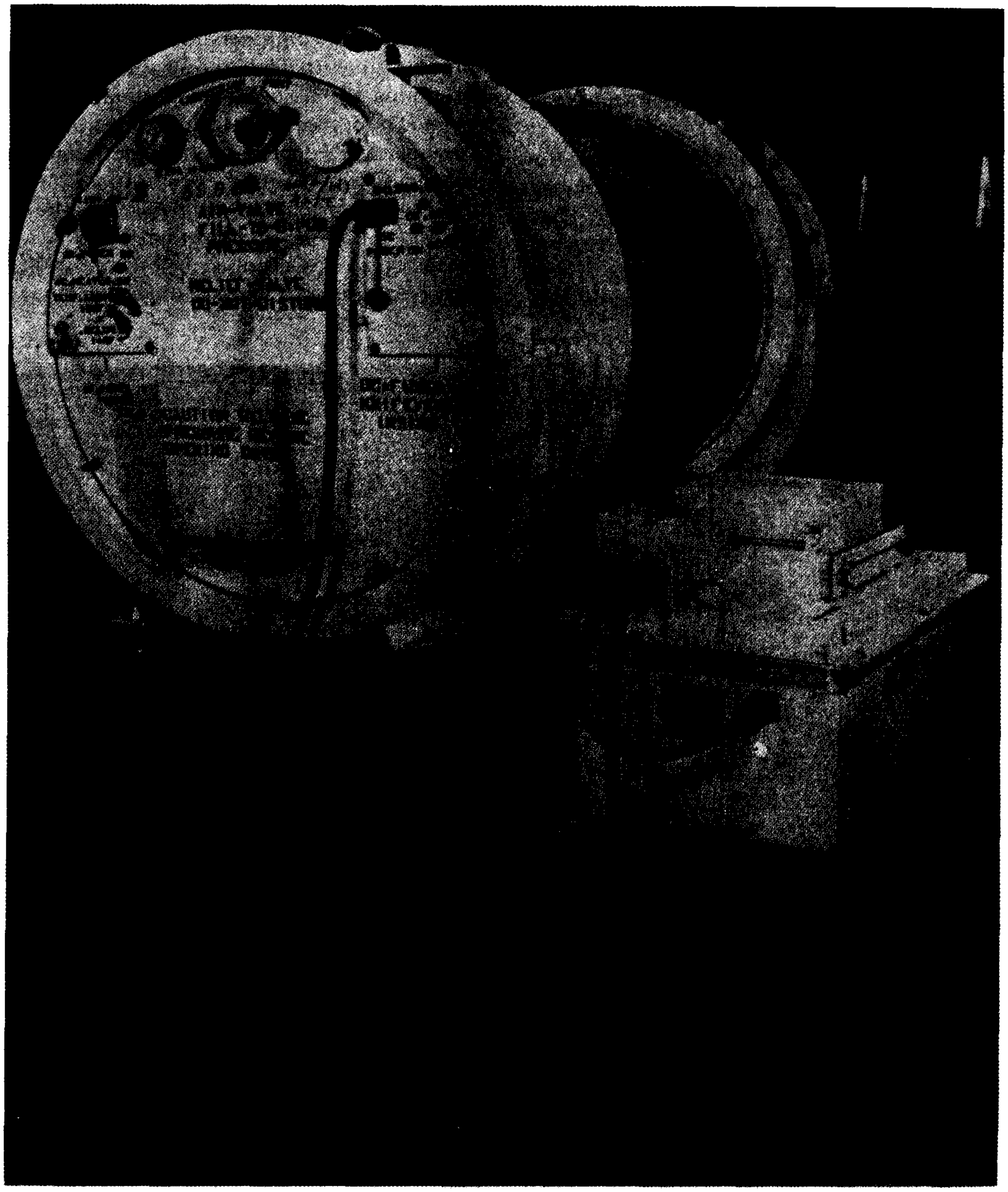


**Figure 12-2. External Battery Power Source for POLARIS Guidance System**

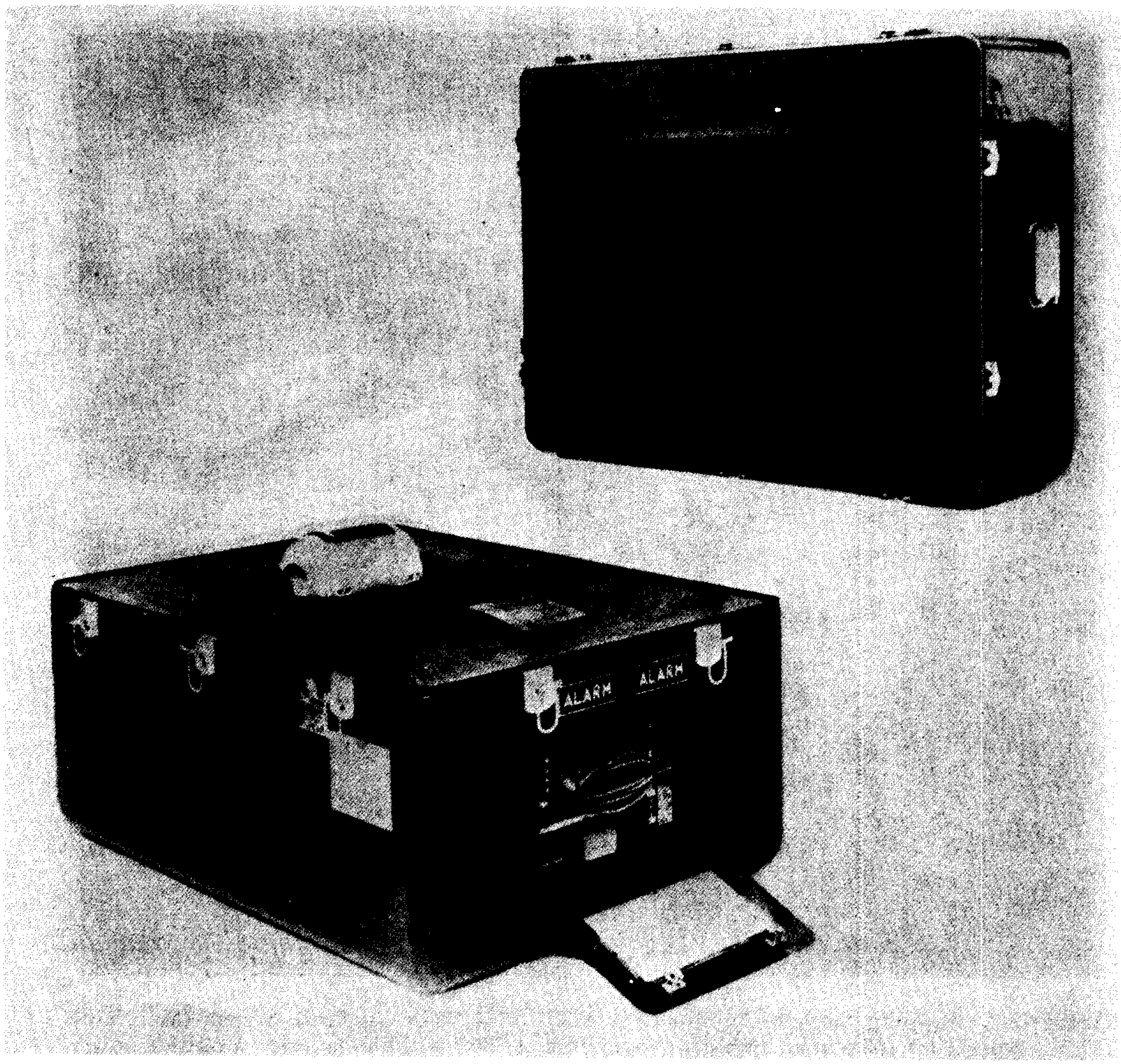



Figure 12-3. Container Using Thermal Battery

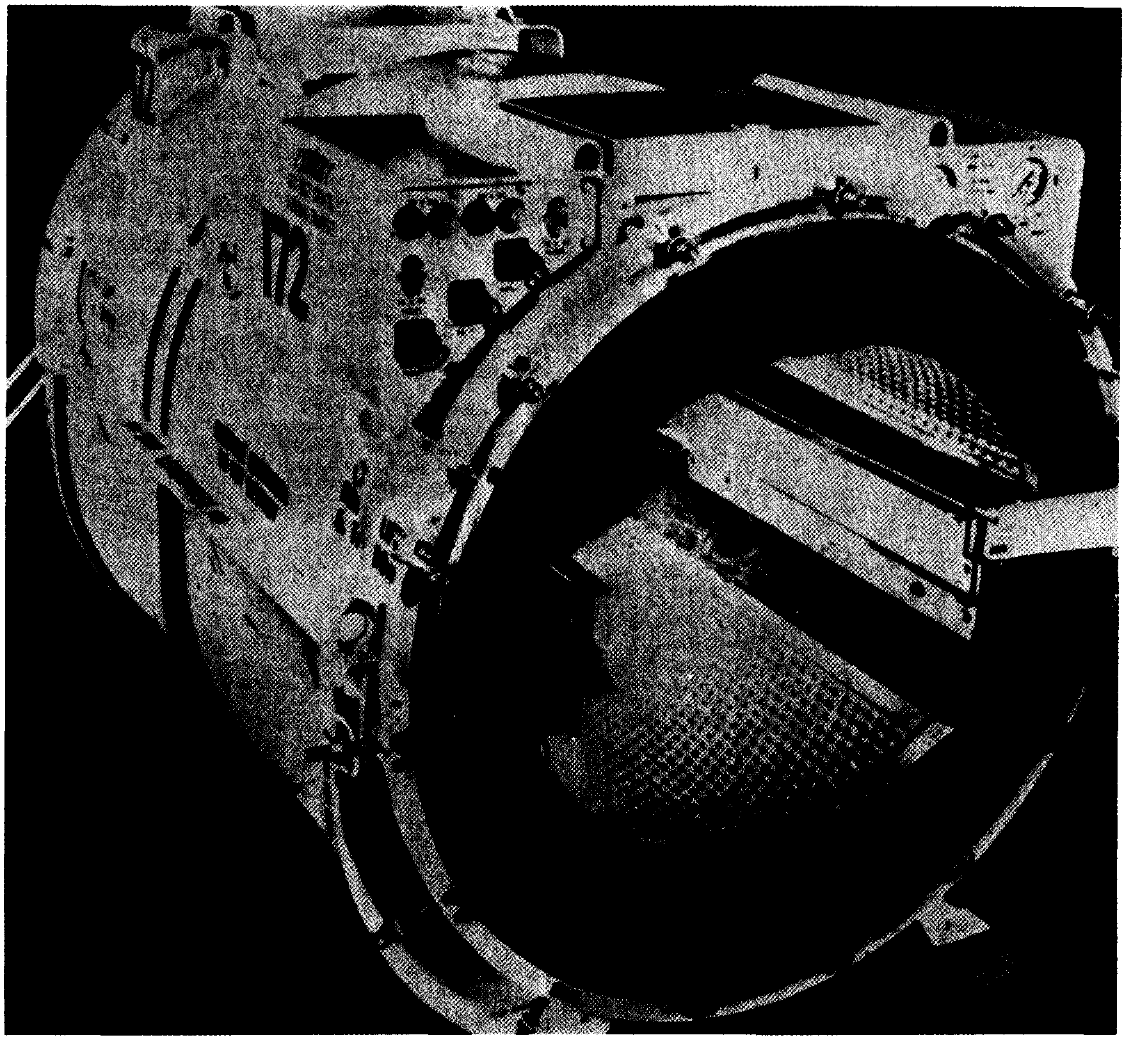


Figure 12-4. Shipping Storage Container for MK 1 POLARIS Guidance System (Maintains 137°F ± 5 deg F for 100 h at an ambient temperature of -20°F without batteries or outside power source.)

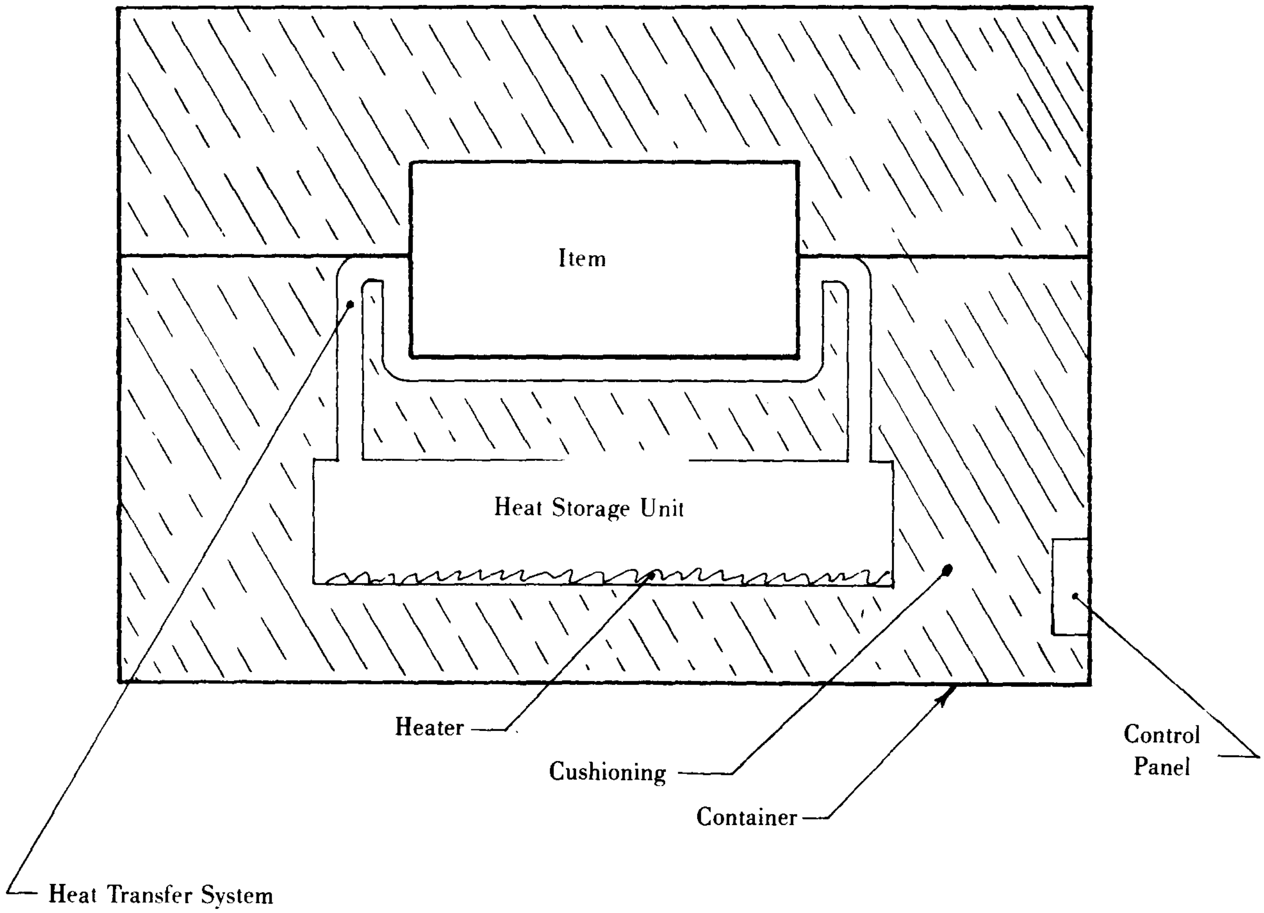



**Figure 12-5. Schematic Drawing of a Container Using Thermophormic Materials for Temperature Control**

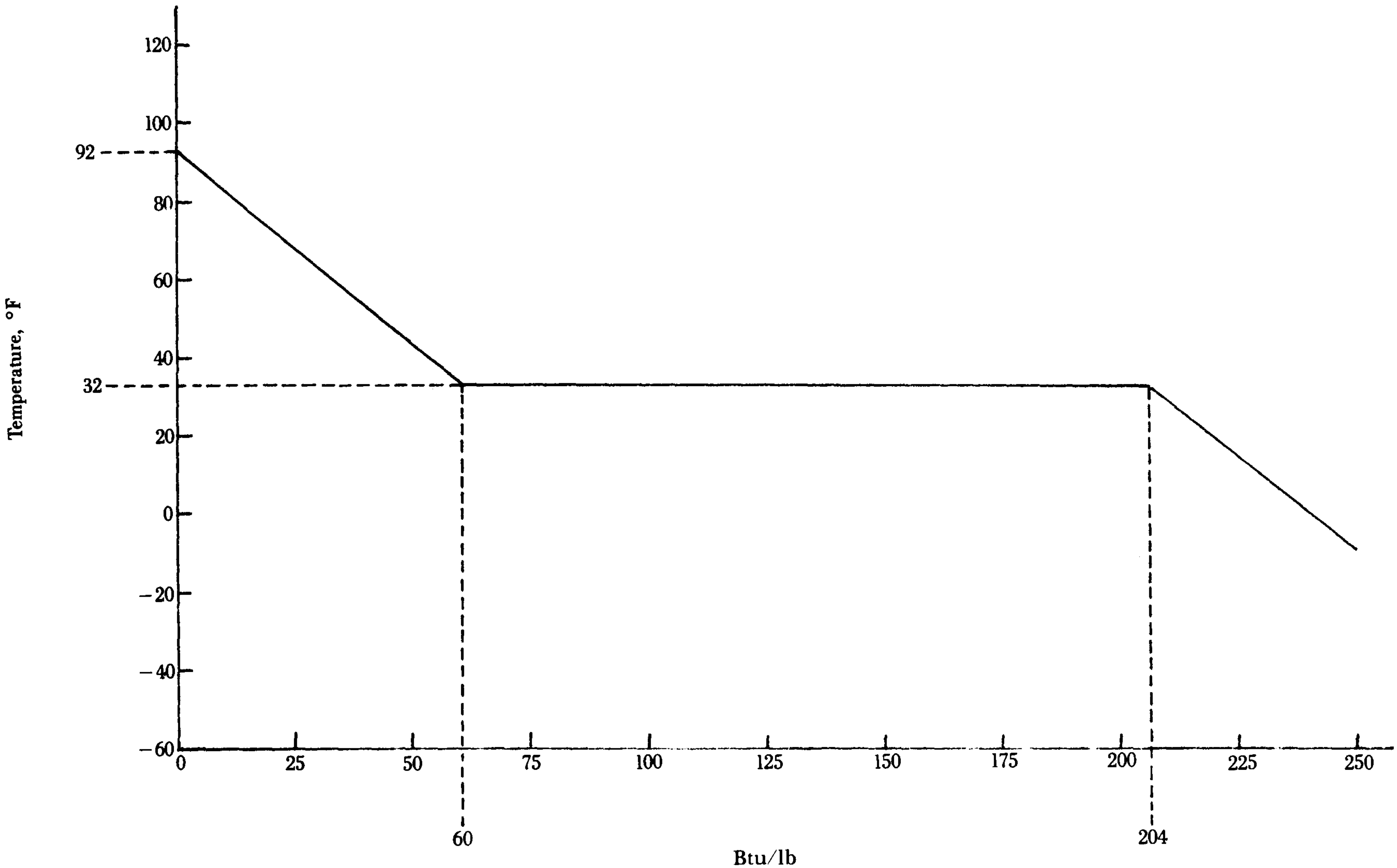



**Figure 12-6. Discharging Cycle of a Heat Storage Material (Water)**

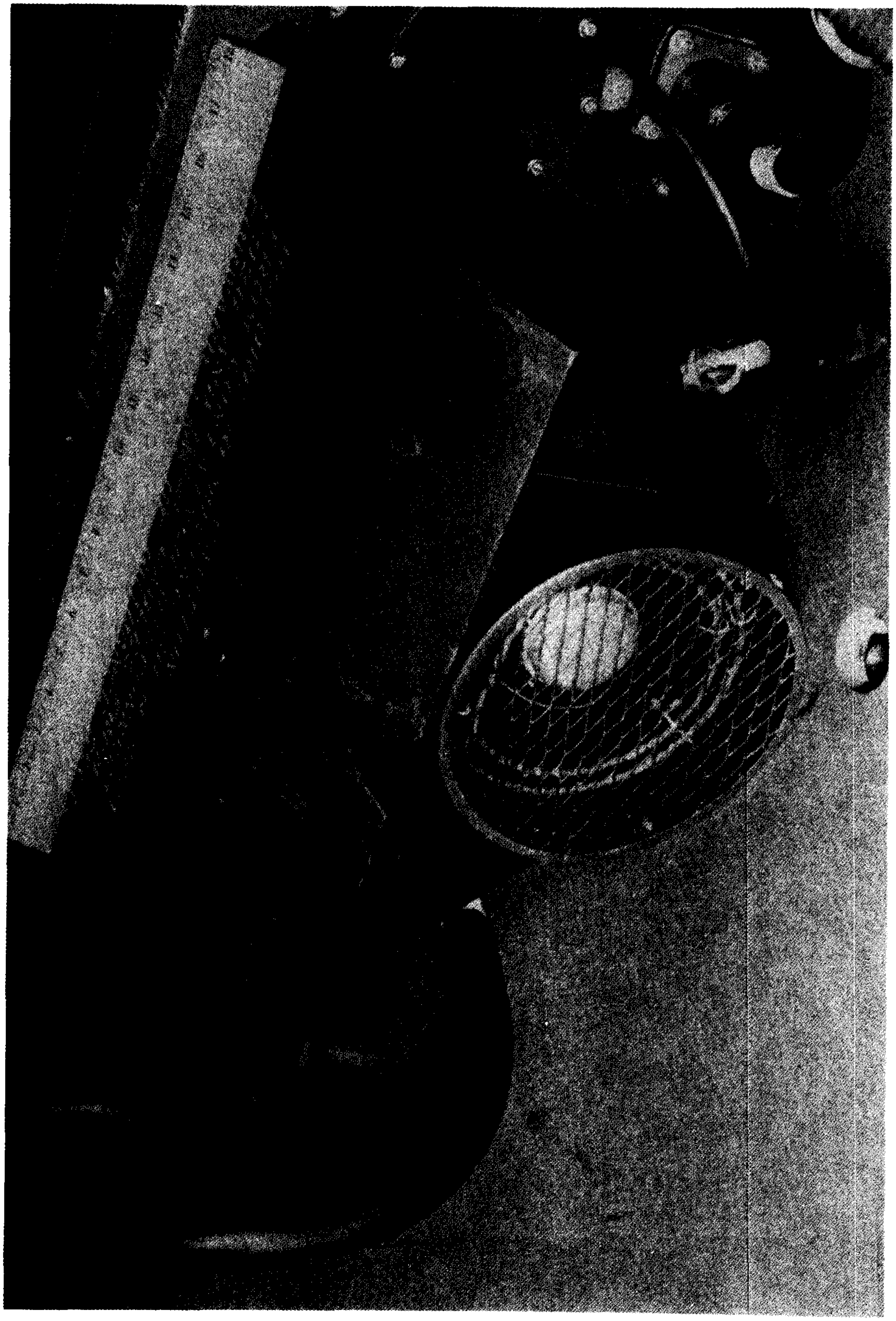


Figure 12-7. Electric Space Heater Installation

# CHAPTER 13
# ELECTROMAGNETIC INTERFERENCE

The modern battlefield with its array of electronic systems presents an environmental hazard that was of little significance prior to World War II. Currently, the development of devices utilizing electrical or electromagnetic phenomena in their operation has been so extensive that few components or systems used for military or civilian purposes exist that do not depend on these phenomena. However, the very nature of the properties associated with the phenomena that enable the devices to perform their purposes may also produce undesired effects on other equipment having different purposes. These undesired interactions can take place at all levels—i.e., between systems, between subsystems of the same system, between equipment in the same systems, and between components in the same "black box". Electromagnetic Interference (EMI) is the phenomenon resulting when electromagnetic energy causes unacceptable or undesirable responses, malfunction, degradation, or interruption of the intended operation of electronic equipment, subsystem, or system. While not an electronic device *per se*, electroexplosive devices (EED) are used extensively in missile/rocket systems to initiate a subsequent action. These EED's are subject to EMI—radiation of the proper frequency and intensity can cause EED's to detonate prematurely with catastrophic results. Repeated exposure of EED's to electromagnetic energy intensities less than that required to initiate them can degrade the device. This degradation may be sufficient to cause the EED to malfunction and, thereby, not fulfill its intended role upon the receipt of a proper signal.

In some cases system degradation can be recognized, for example, a prematurely detonated EED. In other cases, such as in control circuits or degraded EED's, it may be much more difficult — requiring extensive testing — to recognize and identify the cause of system failure.

A missile or rocket is particularly vulnerable because it must be immune to EMI throughout its entire stockpile-to-target sequence. During transportation and storage the missile/rocket may be quite close to urban areas containing relatively high-powered transmitters of both military and broadcast types. Also, the high density of radiating electronic systems in a battlefield environment, including naval components, will present a severely hostile environment.

Contributors to the electromagnetic environment can be divided into three main classes: natural radio noise; signals which are generated purposely to convey information; and spectral components generated incidentally to the functioning of various electrical and electronic devices, and generally classified as man-made noise. Examples of noise sources are:

1. Lightning
2. Solar and cosmic radiation
3. Electrical tools and appliances
4. Fluorescent lighting
5. Automotive ignition systems
6. High-voltage power lines
7. Radars—all types.

Refer to Engineering Design Handbook, *Electromagnetic Compatibility*, DARCOM-P 706-410, for a quantitative discussion of EMI and methods of protection against the hazard.

# CHAPTER 14
# LOGISTICS

*Limitations on the movement of containers and their contents—due to size and weight—imposed by truck, railroad, sea, and air transport and airdrop are presented.*

## 14-1 TRANSPORTATION LIMITATIONS

The limitations imposed upon containers by trucks, railroads, ships, aircraft, and special transporters for overseas areas and the continental U.S. are described in this chapter. The designer usually will find that the regulations and dimensional limitations in overseas areas are more restrictive than in the continental U.S.

Wherever it appears container dimensions will approach the limitations specified in this chapter, or specific problems arise that cannot be resolved by reference to this chapter, then a detailed transportability study should be made for the mode of transportation under consideration. Transportation publications are referenced which will aid the designer in solving transportation problems. Transportation problems should be coordinated at the local Transportation Office as an initial point of contact.

The Department of Transportation (DOT) is responsible for the regulation of shipment and/or movement of explosives and other hazardous materials in interstate commerce by rail, air, highway, and water through its major operating agencies. The authority and responsibilities of the DOT are established by Federal Law in Section 831-835, Title 18 of the US Code for the requirements governing the handling and transport of hazardous materials. These regulations are published in 49CFR parts 170-179 and R.M. Graziano's Tariff Number 25, *Hazardous Materials Regulations of the DOT*. These regulations cover minimum transportation requirements only. The Department of Defense (DOD) and Department of the Army (DA) may supplement DOT requirements when deemed necessary. The transportation of military explosives and other hazardous materials by either military carriers or commercial carriers within continental U.S. is governed by AR 55-355.

## 14-2 TRUCK

Each state in the U.S. has placed upon its highway system limitations affecting the size of loads that can be legally transported over these highways. Although these limitations can be exceeded, to do so causes considerable difficulty and would, in all probability, require special permits, special routing, police escorts, etc. This adds to the in-transit time, and, consequently, the transportation costs. Since these limitations vary according to states, the designer must be aware of the highway limitations. A summary of highway size limitations for individual states is shown in Table 14-1. AR 55-162 provides instructions for securing permits to move military cargo exceeding legal weight or dimensional limitations—either in military owned and operated vehicles or commercial vehicles—over US public highways.

Containers should be designed to permit versatility of transporting through any state without first having to obtain special permits, routing, etc. Generally speaking, the maximum width and height for over-the-road equipment which will meet the general requirements of all states is 8 ft wide by 13.5 ft high. Maximum length of vehicles authorized in all states ranges from 35 ft for single units to 55 ft for tractor-semitrailer units. Nevada permits a length of 70 ft for tractor-semitrailer units, and in many states the law is silent relative to maximum permissible lengths. The floor height of trailers will usually vary from 4 ft 1 in. to 5 ft, depending on the size of the tires used. For flatbed trailers, this leaves a usable stacking height ranging from 8.5 ft to 9 ft 5 in. This is assuming a 13.5-ft maximum road height limitation. Since truck-full trailer units are not allowed in certain states, this type of vehicle should only be considered in special cases. Dimensions of standard military vehicles are contained in data sheets which are available at US Army Tank Automotive Command, Warren, MI 48090, and from FM55-15, *Transportation Reference Data*.

Overseas highway limitations are generally more restrictive than those found in the U.S.; consequently, the carrier and container should not exceed 11 ft in height, 8 ft in width, and 16,000 lb axle load.

Missiles and rockets will be loaded, blocked, and braced in accordance with approved Army loading drawings. In the absence of Army drawings, the published rules of the American Trucking Associations will apply.

# TABLE 14-1. TRUCK AND TRAILER LIMITATIONS BY STATES (from FM 55-15)

## NORTHEASTERN STATES

| STATE | Reciprocity authority (Interstate or International Carriers) | Height | Length, ft: Truck | Length, ft: Trailer or Semitrl. | Length, ft: T.S.T. | Length, ft: T.S.T.T. | Length, ft: Other Comb. | Axle Load, lb | Tandem Axle 4' Apart | Gross Weight, lb: 3 Axle T.S.T. | Gross Weight, lb: 4 or 5 Axle T.S.T. | Gross Weight, lb: Highest Weight Possible |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT | Full reciprocity except $20 P.U.C. plate (C) | 13' 6" | 55 | N.S. | 55 | N.P. | N.P. | 22,400 (N) | 36,000 (N) | 53,800 (N) | 67,400 (W)(N) | 73,000 |
| DE | Full reciprocity (C) | 13' 6" | 40 | 40 | 55 (KK) | 65 | 65 | 20,000 | 36,000 | Table | Table | Table 73,280 Max. |
| DC | Full reciprocity | 12' 6" | 40 | N.R. | 55 | N.P. | 55 | 22,000 | 38,000 | Table | Table | Table 70,000 Max. |
| ME | Full reciprocity except P.U.C. fees (C) | 13' 6" (B) | 56.5 | 45 | 56.5 (BB) | N.P. | 56.5 | 22,000 | 32,000 (T) | Table 51,800 Max. | Table 66,300 (W) | Table 73,280 Max. |
| MD | Full reciprocity (C) | 13' 6" | 40 | 55 | 55 (BB) | 65 (AA) | 55 | 22,400 | 40,000 | Table Q 55,000 Max. | Table (W) (Q) 65,000 Max. | Table (Q) 73,280 Max. |
| MA | Full reciprocity (C) | 13' 6" | 35 | N.R. | 55 | N.P. (M) | N.P. | 22,400 | 36,000 | Table | Table 73,000 Max. | Table 73,000 Max. |
| NH | Full reciprocity except P.U.C. fees (C) | 13' 6" | 35 | N.R. | 55 (BB) | 55 | 55 | 22,400 | 36,000 (E) | Table 52,800 Max. | Table (W) 66,400 Max. | Table 73,280 Max. |
| NJ | Full reciprocity (C) | 13' 6" | 35 | N.S. (F) | 55 | 55 | 55 | 22,400 (V) | 32,000 (V) | Limited by axle (V) | Limited by axle (V) | 73,280 |
| NY | Reciprocity on license; none on mileage tax (C) | 13' 6" | 35 | (FF) | 55 (KK) | 55 (NN) | 55 | 22,400 | 36,000 | 34,000 + (L × 1000) | 34,000 + (L × 1000) 71,000 Max. | 34,000 + (L × 1000) 71,000 Max. |
| PA | Full reciprocity (C) | 13' 6" | 35 | N.S. | 55 | N.P. | 55 | 22,400 (Q) | 36,000 (Q) | 50,000 (Q) | 60,000 (Tax.) (W) (Q) | 73,280 |
| RI | Full reciprocity except P.U.C. fees | 13' 6" | 40 | (FF) | 55 | N.P. | 55 | 22,400 | 36,000 | 50,000 | 67,400 (W) | 73,280 |
| VT | Full reciprocity | 13' 6" | 55 | N.S. | 55 (BB) | N.P. | 55 | 22,400 (T) | 36,000 | Table | Table | 73,280 Max. |

(cont'd on next page)

## TABLE 14-1. TRUCK AND TRAILER LIMITATIONS BY STATES (from FM 55-15) (cont'd)

| SOUTHERN STATES | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length, ft | | | | | | | Gross Weight, lb | | |
| STATE | Reciprocity authority (Interstate or International Carriers) | Height | Truck | Trailer or Semitrl. | T.S.T. | T.S.T.T. | Other Comb. | Axle Load, lb | Tandem Axle 4' Apart | 3 Axle T.S.T. | 4 or 5 Axle T.S.T. | Highest Weight Possible |
| AL | Full reciprocity except P.S.C. filing fee (C) | 13' 6" | 40 | N.S. | 55 | N.P. | N.P. | 18,000 (U) | 36,000 (U) | Table | Table | Table 73,280 Max. |
| AR | Full reciprocity (C) Except C.C. filing fees | 13' 6" | 40 | N.S. | 55 | 65 | 65 | 18,000 | 32,000 | Limited by axle weight | Limited by axle weight | 73,280 Max. (M) |
| FL | Full reciprocity except P.U.C. Iden. Fee | 13' 6" | 35 (K) | (FF) | 55 | N.P. | 55 | 20,000 (U) | 40,000 (U) | Table (U) | Table (U) | Table (U) 66,610 Max. |
| GA | Full reciprocity except P.S.C. fee $1 (C) | 13' 6" | 55 | 55 | 55 (KK) | 55 | 55 | 20,340 | 40,680 | Limited by axle weight | Limited by axle weight | 73,280 Max. |
| KY | Full reciprocity except certificate and permit fees (S)(C) | 13' 6" (M) | 35 (M) | N.S. | 55 (M) (BB) | 65 (M) | 55 (M) | 18,000 (M) (V) | 32,000 (M) (V) | Limited by axle wt. (M) | Limited by axle wt. (M) | 73,280 Max. (M) |
| LA | Full reciprocity (C) | 13' 6" | 35 | N.R. | 60 | N.P. | 65 | 18,000 | 32,000 | Limited by axle weight | Limited by axle weight | 68,000 (J) |
| MS | Full reciprocity except P.S.C. fees (C) | 13' 6" | 35 | N.S. | 55 | 55 | 55 | 18,000 | 28,650 32,000 (M) | Table | Table | Table 73,280 (M) |
| NC | Full reciprocity except P.U.C. filing fee (C) | 13' 6" | 35 (K) | N.R. | 55 | N.P. | 55 | 18,000 (P) | 36,000 (P) | 47,500 (P) | 64,000 (P)(W) | 70,000 (P) |
| SC | Full reciprocity except P.S.C. fees (C) | 13' 6" | 35 (K) | N.S. | 55 (KK) | N.P. | 55 | 20,000 (R) | 32,000 (R)(T) | 50,000 (R) | 65,000 (W) (R) | 73,280 Max. |
| TN | Full reciprocity (C) | 13' 6" | 40 | N.S. | 55 (BB) | N.P. | 55 | 18,000 | 32,000 | Limited by axle | Limited by axle | 73,280 Max. |
| TX | Full reciprocity except on intangible tax (C) | 13' 6" | 40 | N.S. | 65 | 65 | 65 | 18,000 | 32,000 | Table | Table | Table 72,000 Max. |
| VA | Full reciprocity except Corp. Comm. registration fee $2 (C) (S) | 13' 6" | 35 | N.S. | 55 | N.P. | 55 | 18,000 | 32,000 | Table | Table | Table 70,000 Max. |
| WV | Full reciprocity except $3 P.U.C. Card (C) | 13' 6" (M) | 35 (K) | N.S. | 55 (M) | N.P. | 55 (M) | 18,000 (V) | 32,000 (V) | Table (V) | Table (V) | Table (T)(V) 70,000 (M) |

(cont'd on next page)

## TABLE 14-1. TRUCK AND TRAILER LIMITATIONS BY STATES (from FM 55-15) (cont'd)

**CANADIAN PROVINCES**

| STATE | Reciprocity authority (Interstate or International Carriers) | Height | Length, ft | | | | | Axle Load, lb | Tandem Axle 4' Apart | Gross Weight, lb | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Truck | Trailer or Semitrl. | T.S.T | T.S.T.T. | Other Comb. | | | 3 Axle T.S.T. | 4 or 5 Axle T.S.T. | Highest Weight Possible |
| AB | Full reciprocity | 13' 6" | 35 | N.S. | 65 | 65 | 65 | 18,000 | 32,000 | 42,000<br>45,000 (00) | 59,000 (M)<br>74,000 (M) | 74,000 (M) |
| BC | Proration only<br>(Y) (C) | 13' 6" | 35 | 45<br>(FF) | 65<br>(M) | 65<br>(M) | 65<br>(M) | 20,000 | 35,000 | 52,000 (00) | 67,000 (4 ax.)<br>82,000 (5 ax.)<br>(00) | 110,000 (00) |
| MB | Full reciprocity | 13' 6" | 40 | N.S. | 60 | 65 | 65 | 18,000 | 32,000 | 46,000 | 60,000<br>74,000 | 74,000 |
| NB | Full reciprocity except<br>P.U.C. fees (C) | 13' 6" | 35 | 45 | 65 | 65 | 65 | 20,000 | 35,000 | 50,000 | 65,000 (4 ax.)<br>80,000 (5 ax.) | 80,000<br>125,000 (00) |
| NS | Full reciprocity except<br>P.U.C. fees | 13' 6" | 40 | 45 | 65 | N.P. | 65 | 18,000<br>(PP) | 32,000<br>(PP) | 49,000<br>(PP) | (PP)65,000(4 ax.)<br>74,000(5 ax.) | 74,000<br>(PP) |
| ON | Limited Reciprocity | 13' 6" | 35 | 45<br>(KK) | 65 | 65 | 65 | 20,000 | 35,000 | 50,000 | 65,000 (4 ax.)<br>80,000 (5 ax.) | 135,000<br>(T) |
| PE | Full reciprocity except<br>P.U.C. fees | 14' 6" | 40 | N.S. | 70 | 70 | 70 | 20,000 | 35,000 | 50,000 | 65,000 (4 ax.)<br>80,000 (5 ax.) | 80,000 |
| PQ | Full reciprocity except<br>P.U.C. fees | 13' 6"<br>(M) | 35 | 42.5<br>(FF) | 65 | 65 | 65 | 22,000 | 38,000<br>(II) | 54,000<br>(II) | (II)76,000(4 ax.)<br>(II)86,000(5 ax.) | 86,000<br>(II) |
| SK | Reciprocity to private<br>carriers and movers | 13' 6" | 35 | N.R. | 65 | 65 | 65 | 18,000 | 32,000 | Table | Table | Table<br>74,000 Max. |

(cont'd on next page)

## TABLE 14-1. TRUCK AND TRAILER LIMITATIONS BY STATES (from FM 55-15) (cont'd)

| MIDWESTERN STATES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length, ft | | | | | | | Gross Weight, lb | | |
| STATE | Reciprocity authority (Interstate or International Carriers) | Height | Truck | Trailer or Semitrl. | T.S.T. | T.S.T.T. | Other Comb. | Axle Load, lb | Tandem Axle 4' Apart | 3 Axle T.S.T. | 4 or 5 Axle T.S.T. | Highest Weight Possible |
| IL | Full reciprocity except on C.C. fee (Y) (L) | 13' 6" | 42 | 42 | 55 (H) (KK) | 65 (AA) | 60 | 18,000 | 32,000 | Table | Table | Table 73,280 Max. |
| IN | Full reciprocity except P.S.C. filing fee (c) | 13' 6" | 36 | N.S. | 55 (KK) | 65 | 55 | 18,000 (X) | 32,000 (X) | Limited by axle loads | Limited by axle loads | 73,280 Max. |
| IA | Full reciprocity (Y) (C) (L) except C.C. fees | 13' 6" | 35 | N.S. | 55 (G) | 60 | 55 (G) | 18,000 (Z) | 32,000 (Z) | Table (Z) | Table (Z) | Table (Z) 72,634 Max. |
| KS | Full reciprocity (C) (Y) | 13' 6" | 42.5 | (FF) | 55 (KK) | 65 | 65 | 18,000. | 32,000 | Table | Table | Table 73,280 Max. |
| MI | Full reciprocity except P.U.C. fees (C) (Y) | 13' 6" | 40 | N.R. | 55 (KK) | 65 (M) | 55 | 18,000 | 26,000 (I) | Limited by axle loads | Limited by axle loads | Limited by axle loads |
| MN | Full reciprocity (C) (Y) | 13' 6" | 40 | 40 (FF) | 55 | N.P. | 55 | 18,000 | 32,000 | Table | Table | Table 73,280 Max. |
| MO | Full reciprocity (Y) (C) | 13' 6" | 40 | N.S. | 55 (KK) | 65 (AA) | 65 (AA) | 18,000 | 32,000 | Table | Table | Table 73,280 Max. |
| NE | Full reciprocity (Y) (L) (C) | 13' 6" | 40 | (FF) | 60 | 65 | 65 | 18,000 (T) (V) | 32,000 (T) (V) | Table (Q) | Table (Q) | Table (Q) 71,146 Max. (T) |
| ND | Reciprocity on vehicles under 24,000 lb (Y) (C) | 13' 6" | 35 (K) | N.R. | 60 | 65 (M) | 60 | 18,000 | 32,000 | 750 (L + 40) | 750 (L + 40) | 750 (L + 40) 73,280 (GG) |
| OH | Full reciprocity except on mileage tax | 13' 6" | 40 | N.S. | 55 | 65 | 65 | 19,000 | 24,000 (O) (Q) | 38,000 + (L x 900) (Q) | 38,000 + (L x 900) (Q) | 38,000 + (L x 900) 78,000 Max. (Q) |
| OK | Full reciprocity except P.U.C. filing fee (C) (Y) | 13' 6" | 40 | N.S. | 55 (KK) | 65 | 65 | 18,000 | 32,000 | Table | Table | Table 73,280 Max. |
| SD | Full reciprocity (Y) (L) (C) | 13' 6" | 35 | N.S. | 65 | 65 (M) | 65 (M) | 18,000 | 32,000 | Table | Table | Table 73,280 Max. |
| WI | Full reciprocity except P.S.C. filing fee (Y) (L) | 13' 6" | 35 | 35 (HH) | 55 (KK) | N.P. | 55 | 19,500 | 32,000 | Table | Table | Table 73,000 Max. |

(cont'd on next page)

## TABLE 14-1. TRUCK AND TRAILER LIMITATIONS BY STATES (from FM 55-15) (cont'd)

| STATE | Reciprocity authority (Interstate or International Carriers) | Height | Length, ft | | | | | Axle Load, lb | Tandem Axle 4' Apart | Gross Weight, lb | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Truck | Trailer or Semitrl. | T.S.T. | T.S.T.T. | Other Comb. | | | 3 Axle T.S.T. | 4 or 5 Axle T.S.T. | Highest Weight Possible |
| **WESTERN STATES** | | | | | | | | | | | | |
| AK | Full reciprocity | 13' 6" | 40 | 40 | 60 | 65 | 60 | 20,000 | 34,000 | 60,000 Table | 80,000 (4 ax.) 85,000 (5 ax.) Table | Table 100,000 (Max.) (GG) |
| AZ | Proration only (Y) (C) | 13' 6" | 40 | N.R. | 65 | 65 | 65 | 18,000 | 32,000 | Table | Table | Table 76,800 Max. |
| CA | Full reciprocity except Bd. of Equal. fees (Y) (C) | 14' | 40 | 40 | 60 (H) | 65 | 65 | 18,000 | 32,000 | Table | Table | Table 76,800 Max. |
| CO | Reciprocity on registration none on P.U.C. & mileage tax (Y) (C) | 13' 6" (M) | 35 | N.S. | 65 (M) | 65 (M) | 65 (M) | 18,000 | 36,000 | 800 (L + 40) | 800 (L + 40) | 800 (L + 40) |
| HI | Full reciprocity | 13' 6" | 40 | N.S. | 55 | 65 | 65 | 24,000 | 32,000 | 800 (L + 40) | 800 (L + 40) | 800 (L + 40) |
| ID | Authority for full reciprocity but agreements are for proration (Y) (L) (C) | 14' | 35 | N.R. | 60 (KK) | 65 (AA) | 65 | 18,000 | 32,000 | Table | Table | Table 76,800 Max. |
| MT | Full reciprocity except on gross operating revenue tax (Y) (C) | 13' 6" | 35 | N.S. | 60 (H) | 65 (DD) | 65 (DD) | 18,000 | 32,000 | Table | Table | Table 76,800 Max. |
| NV | Reciprocity on registration fees; none on P.S.C. fee or mileage tax (Y) (C) | N.S. | 40 | N.S. | 70 | 70 | 70 (AA) | 18,000 | 32,000 | Table | Table | Table 76,800 Max. |
| NM | Authority for full reciprocity; new agreements on proration (Y) (C) | 13' 6" | 40 | N.R. | 65 | 65 | 65 | 21,600 | 34,320 | Table | Table | Table 86,400 Max. |
| OR | Reciprocity on license fees: none on P.U.C. plates or mileage tax (Y) | 13' 6" (A) | 35 | 35 (CC) | 50 (CC) | 65 (CC) | 50 (CC) | 18,000 (CC) | 32,000 (CC) | Table | Table | Table 76,000 (M) |
| UT | Heavy vehicles subj. to mileage tax or permits (C) | 14' | 45 | 45 | 60 | 65 (DD) | 65 (DD) | 18,000 | 33,000 | Table | Table | Table 79,900 Max. |
| WA | Reciprocity on registration fees: none on P.S.C. and gr. wt. fees (Y) (C) | 13' 6" (A) | 35 | 45 | 65 | 65 | 65 | 18,000 | 32,000 | Table | Table | Table (T) 72,000 Max. |
| WY | Reciprocity on registration fees: none on mileage tax (C) | 14' | 50 | N.S. | 75 | 75 | 75 | 18,000 (T) | 36,000 | Table | Table | Table 73,950 (T) |
| **MEXICO** | | | | | | | | | | | | |
| Mex. | None | 13' 6" | 37 | N.S. | (MM) | N.P. | 60 | 20,000 | 32,000 | 52,000 | 64,000 (4 ax 76,500 (5 ax | 81,000 |

(cont'd on next page)

## TABLE 14-1. TRUCK AND TRAILER LIMITATIONS BY STATES (from FM 55-15) (cont'd)

(A) Automobile transporters allowed 13' 6"; WA & OR—14'.
(B) ME—Load may extend 6" above maximum height.
(C) Have fuel purchase and reporting law.
(D) Double-bottoms—65' on 4-lane highways with annual permit.
(E) 40,000 lb allowed on tandem axles of single unit when both are drive axles.
(F) NJ—Trailers 35'.
(G) IA—Auto transporters, boat transporters, and double-bottoms—60'.
(H) CA stinger-steered truck semitrailer—65'. IL—65' on 4-lane and designated highways. MT—70' plus 5' overhang for auto transporters on stinger-steered with permit. WA—stinger-steered T.S.T. without load 65', with load 70' and nonstinger-steered T.S.T. 60' without load, 65' with load.
(I) On designated highways, 1 pair of tandem axles permitted 32,000 lb, however, 2 pair of tandem axles permitted 32,000 lb on each pair, provided maximum gross combination weight does not exceed 73,280 lb.
(J) Limit only on load carrying axles—load on steering not considered in limits.
(K) Single units—40' if equipped with 3 axles; 35' if 2 axles.
(L) Evidence of reciprocity required on vehicles.
(M) Allowed only on designated highways. MA and NY permitted on Thruway. KY 65' length on toll roads and interstate with permit. KY allows auto transporters 60' with permit.
(N) CT—2% tolerance on axle and gross weight: 73,000 lb absolute maximum.
(O) OH—32,000 lb allowed on axles over 4' apart.
(P) 1,000 lb tolerance on any one axle; 5% tolerance on gross weight.
(Q) OH, PA, & NE, 3% tolerance. MD 1000 lb tolerance. (PA 73,280 max.)
(R) 10% tolerance allowed on gross weight (administered also on axles).
(S) Trucks with 3 axles and all tractors assessed additional road tax of 2¢ per gallon on all fuel used.
(T) WV—May secure permit for weight up to 73,280 lb, no tolerance allowed; limit on regular WV roads 60,800 lb. WA permits up to 76,000 lb on certified routes, SC and ME permit 36,000 lb tandems on state highways. VT allows 5% tolerance on single axles on state highways. Ontario weight on combination limited by number of axles and spacing. NE—20,000 lb single, 34,000 lb tandems and 95,000 lb gross on state highways. WY—allows 20,000 lb on single axle and 101,000 lb gross on state highways.
(U) 10% tolerance allowed.
(V) 5% tolerance allowed.
(W) PA—5 axle T.S.T.—73,280 lb; 4 axle truck-full trailer—62,000 lb.
NC—5 axle T.S.T.—70,000 lb.
CT—5 axle T.S.T.—73,000 lb.
ME, MD, RI, NH, and SC—5 axle T.S.T.—73,280 lb.
(X) IN—22,400 lb single & 36,000 lb tandem axle permitted on roads designated by Highway Commission.
(Y) Have fleet reciprocity by apportioning license fees.
(Z) 8% tolerance on total gross weight or groups of axles; 3% on single or tandem axles.

(AA) MO—65' on all primary and interstate highways; IL and MD—65' on 4-lane and designated roads. ID permits triples of 98' on designated roads; NV—triples of 105' on designated roads.
(BB) KY, ME, MD, NH, TN, & VT auto transporters permitted overhang of bumper of vehicle being transported.
(CC) Oregon State Highway Commission may grant, by resolution or annual permits, semitrailer length to 40'; T.S.T. length to 60'; other combination length to 75'; triples of 105'. Axles of 20,000 lb single and 34,000 lb tandem on all state highways.
(DD) Permit needed for 65'.
(FF) KS—42 1/2' on trailer; N.R. on semitrailer.
NE & RI—40' on trailers, N.S. on semitrailers.
MN—semitrailers and trailers for livestock, boats and autos—45'.
FL & NY—35' on trailers, N.R. on semitrailers.
BC—40' on trailers.
PQ—45' on full trailers.
(GG) ND—need approval on all equipment over 64,000 lb.
AK—gross weight for 8 axle doubles with 60' axle spacing.
(HH) Semitrailer length measured from extreme rear of tractor chassis to rear of trailer.
(II) PQ—New limits effective March 1, 1972.
(KK) Auto transporters—60' in GA, MO, & SC; 60' with annual permit in OK, 65' in DE, ID, & IN; 65' with annual permit in WI, MI—60' plus 3' overhang of vehicle or boat transported and 65' on designated highways; 70' in WY; no limit in ON; 65' in IL on 4-lane and designated highways, 60' on others; NY—55' plus 5' overhang; and KS—60' plus 3' overhang beyond front and 4' beyond rear.
(MM) Mexico—3 axle T.S.T. 45'; 4 axle T.S.T. 47'; 5 axle T.S.T. 60'.
(MN) Doubles allowed in NY except in NY City and Nassau and Suffolk Counties. Turnpike doubles up to 101' on Thruway.
(OO) AB—with 9,000 lb steering: BC—with 12,000 lb steering; and NB—for 8 axle train.
(PP) N.S.—1,000 lb tolerance single axle; 3,000 lb tandem.

N.R. Statute specifies no restriction.
N.P. Not permitted.
N.S. Not specified. (Law is silent.)
T.S.T. Tractor semitrailer.
T.S.T.T. Doubles.
L—In formula—distance between 1st and last axle.
WIDTH All states 96", except AB, BC, CT, MB, NB, ON, RI, & SK; 102" ME on state highways; HI 108".

## 14-3 RAILROAD

Military equipment loaded on DOD-owned cars and on cars belonging to common carriers traveling over the lines belonging to the common carriers within continental U.S. must comply with the loading standards of the individual railroad and those of the Association of American Railroads (AAR). Cars loaded on railroads of foreign countries must meet the standards of the particular country involved. Standard Agreements (STANAG) govern the loading of military equipment on rail lines of the NATO nations. Data on loading in Europe and Asia are contained in FM 55-15 *Transportation Reference Data*. Dimensions and capacities of commonly used railroad cars in the U.S., Europe, and Asia are summarized in Table 14-2.

To promote maximum efficiency of railroad transportation, railroad equipment and loaded rail cars should be within the clearance limitations published by the AAR. Since many of the limitations are dictated by the necessity to clear bridges, tunnels, utility poles, etc.—all subject to change—special equipment and loaded cars should not exceed the published limitations without obtaining clearance of the AAR. Loaded rail cars which exceed the minimum limitations usually will require special routings at restricted speeds. Assistance for oversized loads can be obtained from the Military Traffic Management Command (MTMC) which has knowledge of the possible clearance lines—a result of the Strategic Rail Corridor Network (STRANET) study.

To aid the designer in developing a container for North American and European railroad transportation, standard railroad clearance charts are shown in Figs. 14-1 and 14-2, respectively. It should be noted that the North American rail clearances are applicable to cars having dimensions up to 50.5 ft inside length, 54 ft 8.5 in. coupled length, and 41.25 ft between truck centers. If it is necessary to use longer cars or cars exceeding the other dimensions given, then a special study of clearance limitations should be initiated. FM 55-15 gives standard railroad clearance charts for Asia.

Longer loads may be transported on open-top cars not exceeding the previously given dimensions by overhanging the load on one car or using idler cars. Loads transported by this method must conform to the criteria governing overhanging loads and use of idler cars as given in the AAR Regulations. Containers up to 120 ft may be transported over conventional routes using this method if all other critical criteria are met.

Loading, blocking, and bracing drawings—for

OUTLINE DIAGRAM OF
APPROVED LIMITED CLEARANCES OF ASSOCIATION
OF AMERICAN RAILROADS

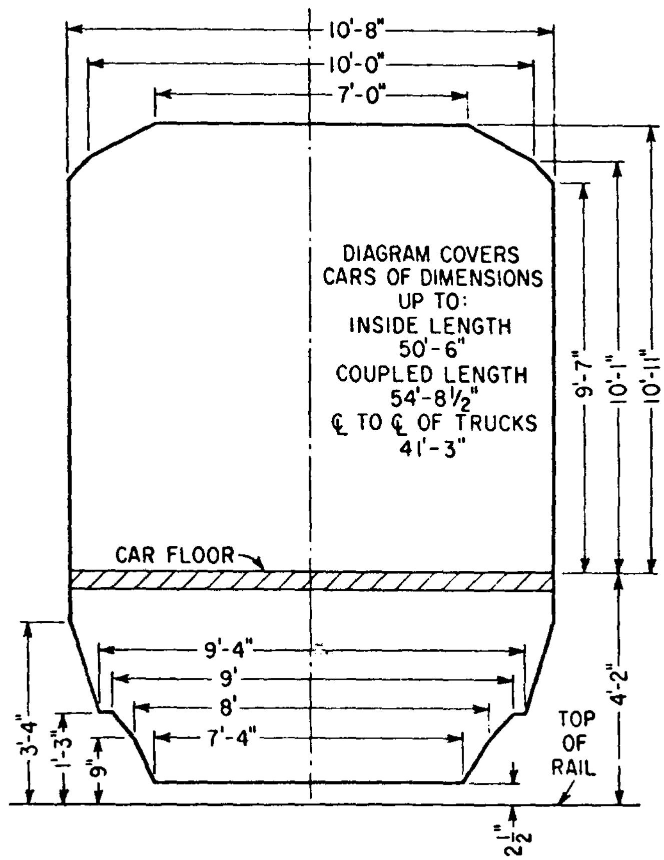



**Figure 14-1. Standard North American Railroad Clearances**

each missile system to be transported by rail—are prepared by the Savanna Army Depot, IL, in accordance with the rules set down by the AAR. Parts of the AAR car loading manual used for the rail shipment of military equipment have been published with other rail loading guidance as Change 1 to TM 55-2200-001-12, *Application of Blocking, Bracing, and Tiedown Materials for Rail Transport*. These rules state permissible weight distribution, location of loads, types, and sizes of material to be used for blocking and bracing, etc. For open-top cars, Sections 1 and 6 of the *Rules Governing the Loading of Commodities on Open-Top Cars* should be consulted. For closed type cars, Pamphlets 27, 41, and 42-B of the *Rules Covering Loading of Carload Shipment of Commodities in Closed Cars* should be consulted. Proposals for deviation from these rules must be submitted to the Defense Traffic Management Service, Washington, DC, through the appro-

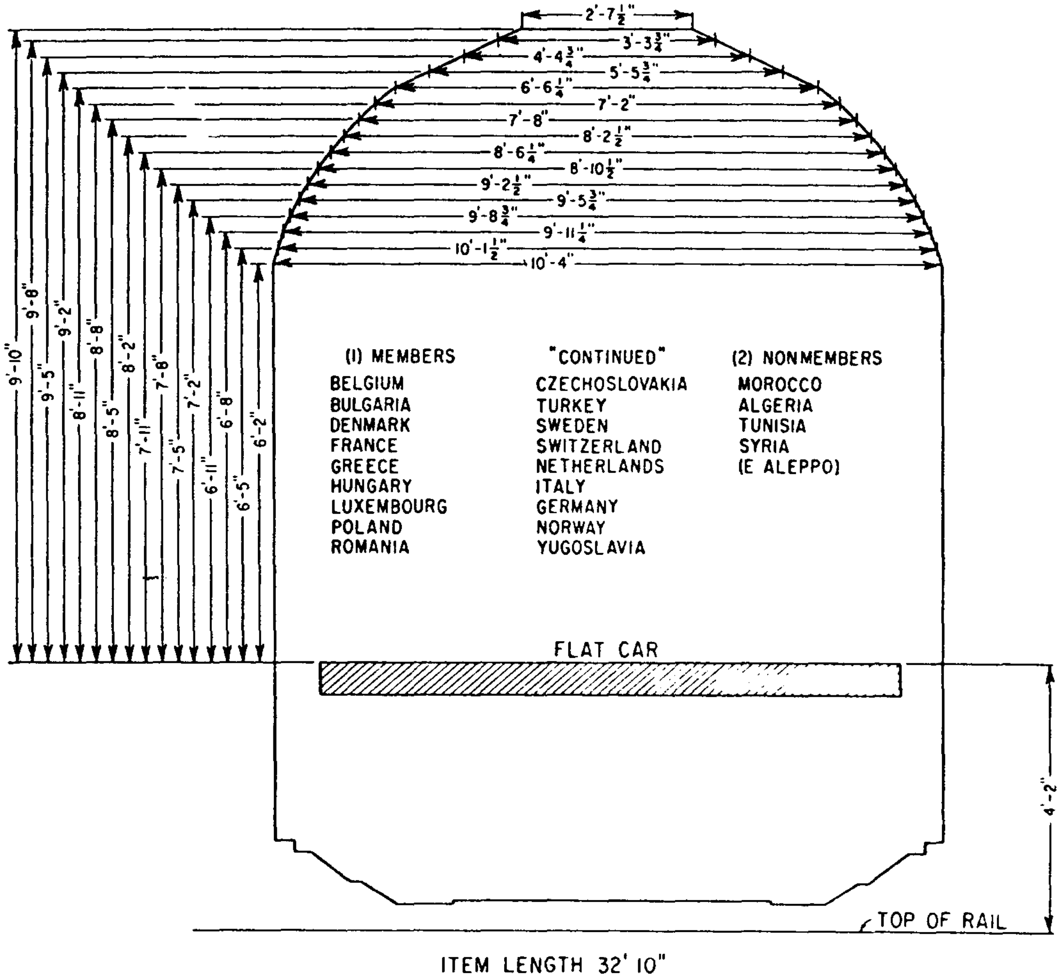



**Figure 14-2. Standard European Railroad Clearances, Berne International**

priate channels, for referral to the Mechanics Division of the AAR.

When designing containers with a specific car size in mind, allowance must be made for blocking and bracing material as specified by the AAR. *Flat* cars require a 6-in. clearance on each side and a 28-in. clearance on each end to allow blocking of the container base. The upper part of the container is restricted to the length of the car used except for those clearances required for the brake wheel (see Fig. 14-3) and to the height and width limitations specified in the clearance diagram, Fig. 14-1. This allows a 10 ft 8 in. maximum width with the height varying from 9 ft 10 in. to 11 ft 2 in., depending on the width of the container.

When loading gondola cars, no clearance is required between the sides and the ends of the cars for blocking except in the vicinity of the brake wheel where the minimum brake wheel clearances will govern as shown in Fig. 14-3. Antichafing material should be placed between the load and the sides and ends of the car to prevent damage to the container.

The most frequently used railroad car on the railroads of North America is the closed car, in particular, the Class X boxcar. When loading containers in boxcars, the dimensional limitations placed upon the container usually will be dictated by the door size. Although special boxcars are available with removable sides and ends for ease in loading, their limited quantity and availability should be a deterrent factor in container design. The dimensions of the majority of Class X boxcars are shown in Fig. 14-4.

Containers too large to fit into closed cars can be transported on open cars—either a gondola car, a flat car, or a depressed-center or well-hole car. Since

**TABLE 14-2**
**DIMENSIONS OF COMMONLY USED RAILROAD CARS**

| Type of Car | Nationality | Inside Length | Inside Width | Inside Height | Weight Capacity, Ton | Side Door Width | Side Door Height |
|---|---|---|---|---|---|---|---|
| Open | N. American (flat) | 41' 6" | * | — | 40 | — | — |
| | | | | | 70 | | |
| | | 42' 6" | * | | | | |
| | | 45' 0" | * | | | | |
| | | 49' 0" | * | | | | |
| | | 50' 0" | * | | | | |
| | | 52' 0" | * | | | | |
| | | 52' 6" | * | | | | |
| | | 53' 6" | * | | | | |
| | N. American (gondola) | 41' 6" | 9' 6" | — | Up to 70 | — | — |
| | | 46' 0" | 9' 6" | | | | |
| | | 48' 6" | 9' 1" | | | | |
| | | | 9' 5" | | | | |
| | | | 9' 6" | | | | |
| | | 52' 6" | 9' 6" | | | | |
| | Turkey and Greece (flat) | 60' 9" | 8' 9" | — | 35 | — | — |
| | | 49' 4" | 8' 9" | | 40 | | |
| | Turkey and Greece (gondola) | 24' 7" | 8' 10" | — | 15 | — | — |
| | | 26' 9" | 8' 10" | | 15 | | |
| | Japan | 18 - 42' | 7'6"-8'6" | — | — | — | — |
| | Britain | 17 - 20' | 7'6"-8'6" | — | — | — | — |
| | France | 20 - 25' | 7'6"-8'6" | — | — | — | — |
| | West Germany (flat) | 32' 2.5" | 8' 9" | — | 16.5 | — | — |
| | | 35' | 8' 6" | — | 22.1 | — | — |
| | | 34' 8.5" | 9' 2" | — | 27 | — | — |
| | | 40' | 8' 11" | — | 25.3 | — | — |
| | | 41' 6" | 8' 9" | — | 23.1 | — | — |
| | | 48' 2" | 8' 9" | — | 40.2 | — | — |
| | | 59' 2.5" | 9' 1/4" | — | 44.1 | — | — |
| | | 60'8" | 8' 11" | — | 61.6 | — | — |
| | | 40' 8.75" | 8' 6" | — | 55.1 | — | — |
| | West Germany (gondola) | 29' 7" | 8' 6" | — | 23.1 | — | — |
| | | 27' 7" | 9' | — | 24.6 | — | — |
| | | 28' | 8' | — | 28.6 | — | — |
| | | 28' 8.5" | 9' 0.37" | 4' 11" | 27.5 | — | — |
| | | 28" | 8' 9" | 4' 10" | 27.5 | — | — |
| | | 28' 7.3" | 9' 0.5" | 4' 11" | 27 | — | — |
| | Vietnam (flat) | — | — | — | 11 | — | — |
| | | — | — | — | 28 | — | — |

(cont'd on next page)

**TABLE 14-2**
**DIMENSIONS OF COMMONLY USED RAILROAD CARS (cont'd)**

| Type of Car | Nationality | Inside Length | Inside Width | Inside Height | Weight Capacity, Ton | Side Door Width | Side Door Height |
|---|---|---|---|---|---|---|---|
| | Vietnam (gondola) | 18'<br>36' | 7' 2.5"<br>8' 2.5" | 3' 4.5"<br>3' 6" | 11<br>28 | —<br>— | —<br>— |
| | Korea (flat) | 34' 6" | 10' | — | 50 | — | — |
| | Korea (gondola) | 33' | 8' 8" | 5' 9" | 33 | — | — |
| Closed | N. American | 40' 6"<br><br><br>50' 6" | 8' 6"<br><br>9' 2"<br>8' 6"<br>9' 2" | 9' load height | 37.5<br>50 | 8' 8"<br>10' and<br>15' | 10' |
| | Turkey and Greece | 24' 7"<br>32' 10" | 8' 10"<br>8' 10" | —<br>— | 15<br>15.75 | —<br>— | 6' 10" |
| | Japan | 17 - 23' | 7' 6" | 6'6"-7'6" | — | — | — |
| | Britain | 17' | 7' 6" | 6'6"-7'6" | — | 5' | 6' |
| | France | 30' | 7' 6" | 6'6"-7'6" | — | — | — |
| | West Germany | 25' 11.8"<br>39' 5.3"<br>24' 10"<br>30' 5.7"<br>28' 8.8"<br>28' 8.6" | 8'<br>8' 11"<br>8' 10"<br>8' 8.7"<br>9' 0.8"<br>8' 11" | 7' 4.5"<br>9' 0.6"<br><br>8' 9.5"<br>5' 6.2"<br>7' 1.5" | 16.5<br>23.1<br>23.1<br>23.1<br>30.8<br>29.7 | 4' 11"<br>6' 6"<br>5' 6"<br>5' 10.8"<br>5' 10.8"<br>12' 8.8" | 6' 7"<br>6' 7"<br>6'<br>6' 7.1"<br>4' 10.7"<br>6' 6.7" |
| | Vietnam | 17' 9"<br>43' | 7'<br>8' 4" | 6' 6"<br>6' 6" | 11<br>27.6 | 4' 9"<br>6' | 6' 3"<br>5' |
| | Korea | 33' 6" | 8' 9" | 6' 10.7" | 33 | 5' | 5' 11" |

*Inside widths for each length listed are: 8' 6", 9' 2", 9' 6", 10' 2", and 10' 6"

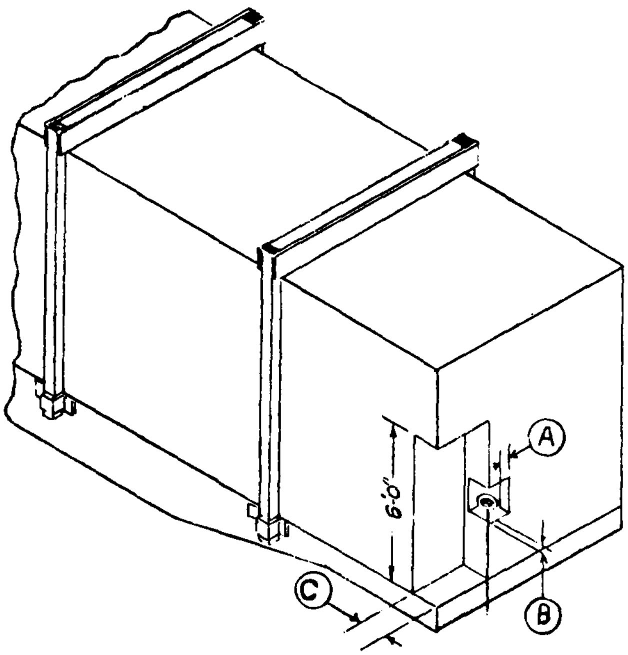
flat cars and gondola cars are open—and the lading becomes, in effect, an extension of the car—the actual container limitations are imposed by the right-of-way clearance limits indicated in Fig. 14-1. The limiting dimensions of the majority of gondola cars are shown in Fig. 14-5. The limiting dimensions of the majority of flat cars are shown in Fig. 14-6. For depressed-center flat and well-hole cars, the well length is also a limiting dimension.

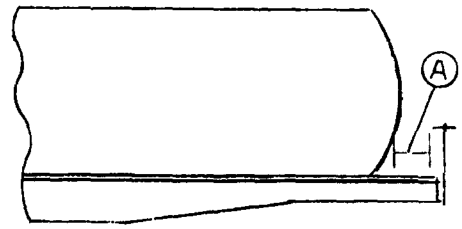
Flat cars and open-top cars are preferred because of their ease of loading and unloading. Closed cars are more difficult to load, block, and brace—especially where larger type containers are involved. It should be noted, however, that open-top cars offer no protection against the elements. Therefore, it may be more advantageous to employ closed cars, especially if secrecy is desired.

For additional information on the sizes of all available rail equipment on the North American continent, consult the *Car Builders Cyclopedia* and *The Official Railway Equipment Register*.

## 14-4 SHIP

Any container that can be transported to dock side can be handled and loaded on board ship. While special handling equipment can be made to load any given weight a ship can carry, the container designer should endeavor to limit the weight of individual containers and their contents to the boom capacity of the vessel in order to permit loading and unloading




Brake Wheel Clearance. The brake wheel clearance must not be less than requirements shown in drawing and should be increased as much as consistent with proper location of load.

A 6-in. clearance in back, on both sides of, and above brake wheel, except as shown for tanks and similar shapes in one piece.

B 4-in. clearance underneath brake wheel.

C 12-in. minimum clearance from end of car to load, extending from center of brake wheel to side of car and 6 ft above car floor. On gondola cars this space may be utilized from floor of car to 4 in. below bottom of brake wheel, Item "B".

Brake wheel clearance should be increased as much as consistent with proper location of load.

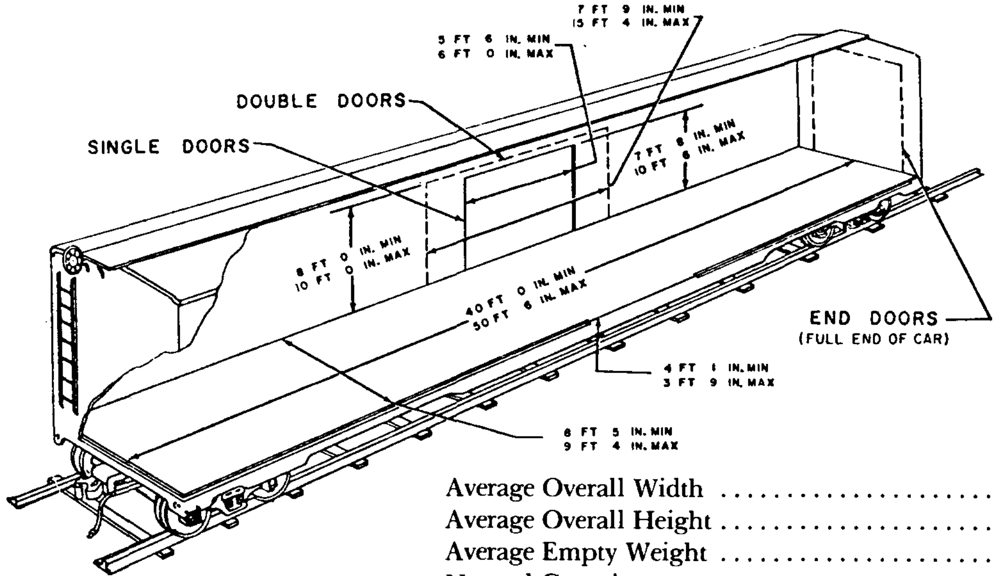
**Figure 14-3. Brake Wheel Clearances**

without use of shore equipment. Since all cargo ships are equipped with at least a 5-long ton boom (long ton equals 2240 lb), it may be assumed that this weight limit could be loaded and unloaded anywhere by any type of vessel. In certain instances, it is feasible to double this capacity by using two 5-ton booms in parallel; however, this procedure limits the area of the ship in which items can be stowed. For containers containing explosives, the Coast Guard has placed various weight limitations on all hoisting equipment according to the class of explosive. These limitations may be found in Coast Guard Regulations CG 108.

Length and width limitations of containers for in-hold storage can be derived from the hatch sizes given in Figs. 14-7, 14-8, and 14-9. Containers longer than the dimensions given in these figures sometimes can be stored below deck by slightly tipping the container, assuming that the height of the container does not exceed the height of the hold or compartment in which it is to be stowed. The heights of tween deck holds* will range between 6 ft to 12 ft, while the heights of the lower holds will vary between 7 ft to 25 ft.

Containers are not restricted to in-hold stowage, but may use "on deck" stowage in accordance with CG 108. While "on deck" stowage will remove the restrictions placed upon containers by hatch and hold sizes, other size limitations will be placed upon the container depending upon the type and size of vessel to be used. The "on deck" stowage limitations in most cases will be less restrictive than those for below deck stowage. If this type of stowage is used,

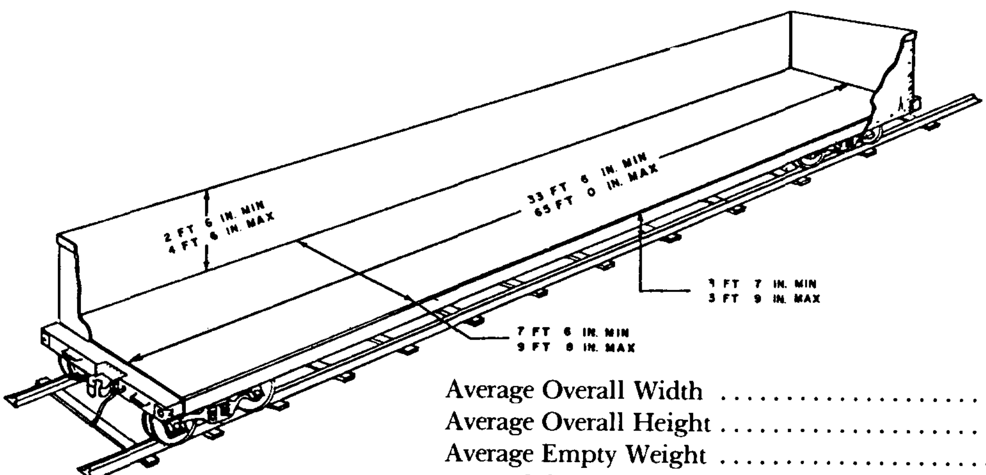
*Tween deck hold (a space located between the weather or main deck and lower hold)




Average Overall Width ................................ 10 ft 8 in.
Average Overall Height ................................ 15 ft 1 in.
Average Empty Weight ................................ 24.1 tons
Normal Capacity ................................ 40 to 50 tons

Note:
For oversize loads, cars with removable sides and ends are available in limited quantity.

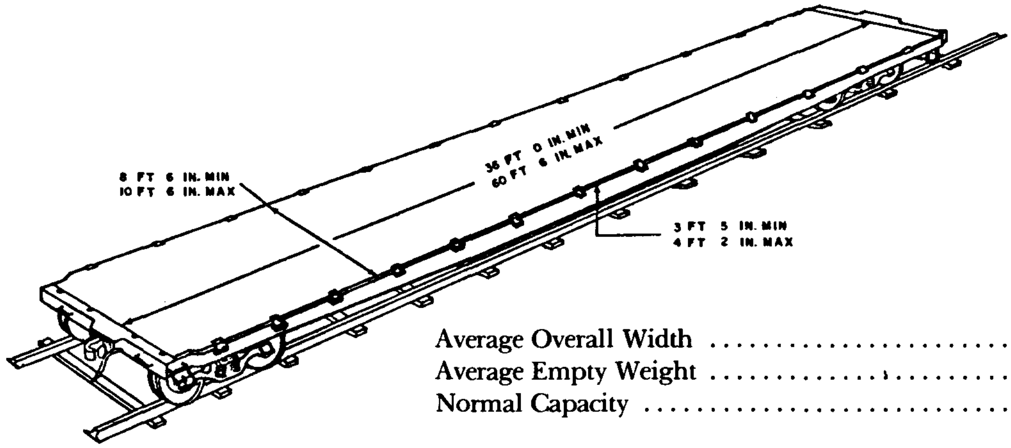
**Figure 14-4. Closed Car Limitations**




Average Overall Width ................................ 10 ft 4 in.
Average Overall Height ................................ 8 ft 7 in.
Average Empty Weight ................................ 21.4 tons
Normal Capacity ................................ 50 to 70 tons

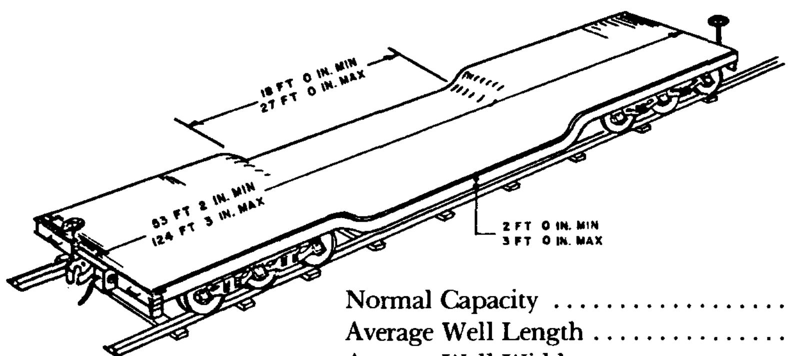
Note:
No clearance required for blocking or bracing. Use antichafing material between sides of container and car wall to prevent container damage.

**Figure 14-5. Gondola Car Limitations**



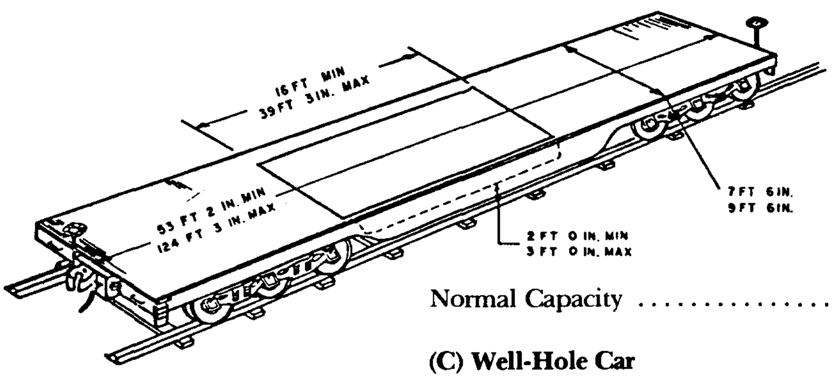

Average Overall Width ........ 10 ft 3 in.
Average Empty Weight ........ 24.35 tons
Normal Capacity ........ 50 to 75 tons

**(A) Flat Car**




Normal Capacity ........ 150 to 170 tons
Average Well Length ........ 24 ft 2 in.
Average Well Width ........ 8 ft 6 in.
Average Well Height ........ 2 ft 6 in.

**(B) Depressed-Center Flat Car**

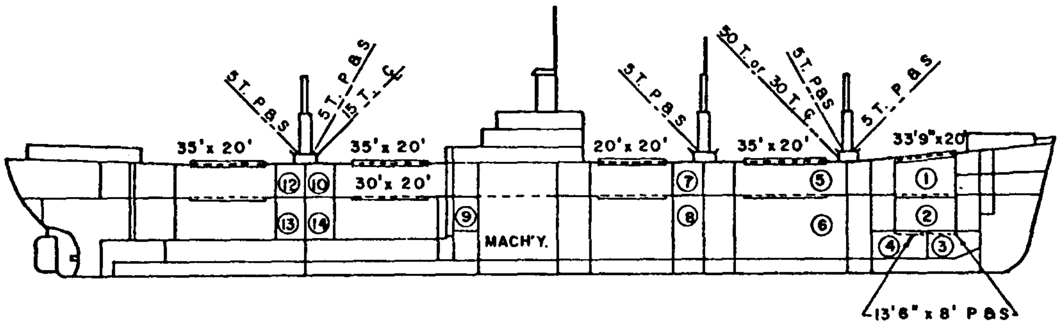



Normal Capacity ........ 97.5 to 125 tons

**(C) Well-Hole Car**

**Figure 14-6. Flat Car Limitations**

MARITIME ADMINISTRATION DESIGN EC2-S-C1
LIBERTY CLASS

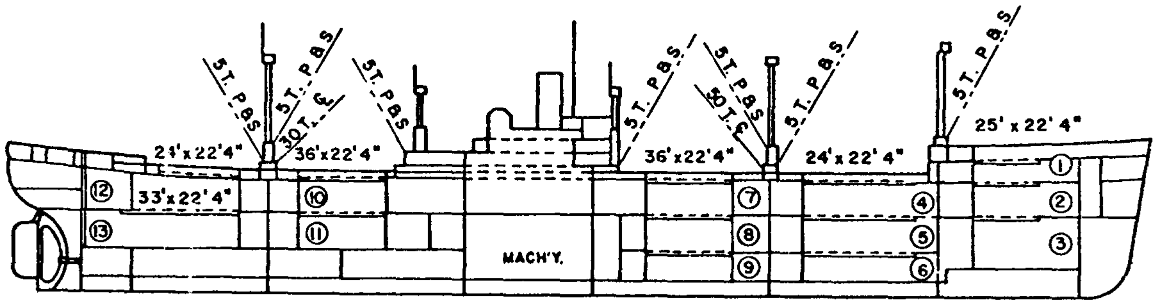



P - Port Left Side S - Starboard Right Side T - Long Tons

| Compt. No. | Cargo Bale, ft$^3$ | Clearance Under Hatch Girder |
|---|---|---|
| 1 | 39,322 | 12'- 1" |
| 2 | 36,083 | 12'- 6" |
| 3 | 5,733 | 7'-10" |
| 4 | 10,873 | 7'-10" |
| TOTAL | 92,011 | |
| 5 | 42,630 | 8'-10" |
| 6 | 92,008 | 22'- 6" |
| TOTAL | 134,638 | |
| 7 | 23,904 | 7'-10" |
| 8 | 59,793 | 22'- 7" |
| TOTAL | 83,697 | |
| 9 | 24,530 | 11'- 6" |
| 10 | 29,689 | 7'-10" |
| 11 | 52,574 | 22'-11" |
| TOTAL | 106,793 | |
| 12 | 30,864 | 7'-10" |
| 13 | 51,571 | 24'- 7" |
| TOTAL | 82,435 | |
| GRAND TOTAL | 499,574 | |

**Figure 14-7. Liberty Class Ship Configuration**

MARITIME ADMINISTRATION DESIGN VC2-S-AP3
VICTORY CLASS

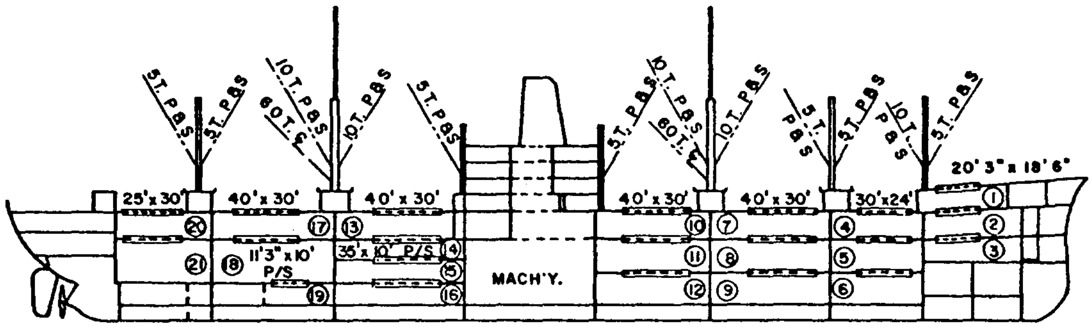



P - Port Left Side S - Starboard Side T - Long Tons

| Compt. No. | Cargo Bale, ft³ | Clearance Under Hatch Girders |
|---|---|---|
| 1 | 18,730 | 6'- 7" |
| 2 | 23,785 | 9'- 8" |
| 3 | 27,910 | 15'- 4" |
| TOTAL | 70,425 | |
| 4 | 27,010 | 8'- 5" |
| 5 | 21,805 | 7'- 7" |
| 6 | 27,945 | 11'- 4" |
| TOTAL | 76,760 | |
| 7 | 45,555 | 8'- 1" |
| 8 | 37,795 | 7'- 7" |
| 9 | 52,840 | 11'- 4" |
| TOTAL | 136,190 | |
| 10 | 49,200 | 8'- 0" |
| 11 | 51,100 | 10'- 4" |
| TOTAL | 100,300 | |
| 12 | 43,630 | 10'- 7" |
| 13 | 25,905 | 10'- 4" |
| TOTAL | 69,535 | |
| | | |
| | | |
| GRAND TOTAL | 453,210 | |

**Figure 14-8. Victory Class Ship Configuration**

MARITIME ADMINISTRATION DESIGN C4-5-1a
MARINER CLASS




P - Port Left Side S - Starboard Right Side T - Long Tons

| Compt. No. | Cargo Bale, ft³ | | Clearance Under Hatch Girders | Compt. No. | Cargo Bale, ft³ | | Clearance Under Hatch Girders |
|---|---|---|---|---|---|---|---|
| | Dry | Refriger'd | | | Dry | Refriger'd | |
| 1 | 16,085 | | 7' - 7" | 13 | 41,775 | | 8' - 3" |
| 2 | 18,140 | | 10' - 8" | 14 | 16,388 | 16,256 | 7' - 7" |
| 3 | 12,210 | | 11' - 7" | 15 | 16,022 | 13,998 | 7' - 11" |
| TOTAL | 46,435 | | | 16 | 38,135 | | 10' - 6" |
| 4 | 29,255 | | 9' - 7" | TOTAL | 112,320 | 30,254 | |
| 5 | 34,592 | | 14' - 3" | 17 | 38,610 | | 8' - 2" |
| 6 | 25,476 | | 13' - 10" | 18 | 65,850 | | 16' - 10" |
| TOTAL | 89,323 | | | 19 | 11,930 | | 10' - 6" |
| 7 | 42,000 | | 8' - 9" | TOTAL | 116,390 | | |
| 8 | 58,150 | | 12' - 9" | 20 | 25,095 | | 7' - 10" |
| 9 | 51,375 | | 13' - 5" | 21 | 34,220 | | 18' - 3" |
| TOTAL | 151,525 | | | TOTAL | 59,315 | | |
| 10 | 40,255 | | 8' - 4" | | | | |
| 11 | 60,020 | | 12' - 4" | | | | |
| 12 | 61,140 | | 13' - 5" | GRAND TOTAL | 736,723 | 30,254 | |
| TOTAL | 161,415 | | | | | | |

**Figure 14-9. Mariner Class Ship Configuration**

the container will be afforded very little protection against the elements during its voyage. In any case, regardless of "on deck" stowage or in-hold stowage, the weight limitations placed upon the container in loading will remain the same.

For easy stowage aboard most vessels, the container dimensions should not exceed 35 ft in length, 20 ft in width, and 11 ft 4 in. in height. To permit container loading and unloading by the smallest type of vessel using only the facilities of the ship, a weight limitation of 11,200 lb for nonexplosive items and 7,467 lb for containers containing complete missiles with high explosive warheads and solid or liquid propellant motors must be adhered to. If two 5-ton booms are hooked in parallel or one 10-ton boom is used, then these weight limitations will be doubled. For weight limitations of other types of explosives, preparation of holds and compartments, and other stowage limitations, *Rules and Regulations for Military Explosives and Hazardous Munitions — CG 108* should be consulted.

If containers exceeding the previously stated limitations are offered for water shipment, contact the Defense Traffic Management, Washington, DC, for guidance.

## 14-5 AIRCRAFT

When designing containers for the required degree of air transportability, careful consideration must be given to the limitations imposed by the characteristics of the aircraft involved. The most important of these characteristics are:

a. Maximum allowable aircraft payload

b. Size, location, and configuration of door openings

c. Size and configuration of cargo compartments to include limiting features that may prevent full use of available space

d. Strength of the aircraft floor and loading ramp

e. Number, location, and strength of tie-down fittings

f. Forward and aft aircraft center of gravity limits.

Containers designed for air transportation should be designed to be transportable in the maximum number of types of available aircraft, thus alleviating the possible shortage of a particular type. Table 14-3 provides dimensional data for selected Army and Air Force aircraft. Tables 14-4 and 14-5 provide data on maximum package sizes for various military aircraft. For more detailed dimensional and loading data, refer to the appropriate Army or Air Force Field Manual—e.g., FM55-13/AFM 76-12, *Air Transport of Supplies and Equipment: Standard Loads in Air Force C-5 Aircraft*. The use of and dependence on civilian carriers to provide airlift support to all US armed services is an integral part of contingency planning. Accordingly, capacities of commercial carriers are shown in Table 14-6. For data on loading, door openings and locations, and maximum package sizes refer to MACP 55-41, *Civil Reserve Fleet (CRAF) Load Planning Guide*, published by the Military Airlift Command, Department of the Air Force. (Table 14-7 shows maximum package sizes for the A-300 aircraft; these data are not included in the referenced CRAF guide.)

When considering weight limitations for air transportability, caution must be exercised on problems of floor loading. The designer must allow sufficient bearing area at the surface of contact between the container and the aircraft floor to remain within the floor loading limitations. This limitation will usually vary between 100 to 500 psi, depending on the type of aircraft used. Limitations on the maximum air transportable payload is also a function of range. The relationship between payload and range for various helicopters is shown in Fig. 14-10.

When external transport by helicopter is proposed, the container suspension provisions must allow the sling web to be inclined at an angle 45 deg from the vertical toward the center of gravity of the suspended container without damaging the container when a force equal to its own weight is exerted on any or all of the sling webs.

An inherent characteristic of a helicopter is the cyclic vertical motion produced by the periodic loading and unloading of the blades. This is a low frequency motion, and special consideration must be given for airborne loads to be carried in helicopters. Vertical motion fluctuation generally is a function of the number of blades in the rotor and the rotor rpm. As a rule, the predominant frequency is given by

$$W = \frac{BN}{60}, \text{ Hz} \tag{14-1}$$

where

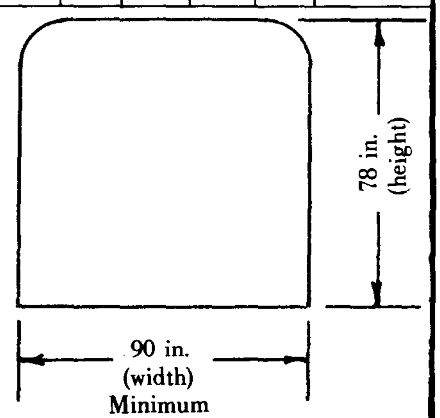
$W$ = natural frequency, Hz
$B$ = number of blades in rotor
$N$ = revolutions per minute, rpm.

**TABLE 14-3. DIMENSIONAL DATA FOR SELECTED ARMY AND AIR FORCE AIRCRAFT**

| | HELICOPTERS | | | | FIXED-WING AIRCRAFT | | | |
|---|---|---|---|---|---|---|---|---|
| | CH-47C, CHINOOK | CH-54B TARHE | UH-ID/H HUEY | UH-60A BLACKHAWK | U-21A UTILITY | C-130E HERCULES | C-135B STRATOLIFTER | C-141A STARLIFTER |
| Cargo Door: | | | | | | | | |
| dimension, width/height, in. | 90/78; 35/63; 33.8/35.3 | 114/92 | 74/49 | 69/54.5 | 53.5/51.5 | 120/108 | 78/116.4 | 135.25/109.2 |
| location | rear; right; belly | pod, rear | each side of fuselage | rear & each side of fuselage | left | rear | fwd left | rear |
| Cargo Compartment: | | | | | | | | |
| length usable, in. | ← 362.5 → | 329 | 92 | 151 | 150 | 492 | 860 | 840 |
| width floor, in. | ← 90 → | 104 | 96 | 72 | 55 | 123 | 129 | 123 |
| height clear of obstruction, in. | ← 78 → | 78 | 49 | 52 | 57 | 109 | 84 | 109 |
| space optimum, $ft^3$ | ← 1,487 (total) → | 1,599 | 220 | 327 | 272 | 3,817 | 5,392 | 6,517 |
| Maximum Payload, tons | ← 11.5 (total) → | — | 2 | 3.8 | 1.75 | 33.5 | 38.5 | 32.2 |
| External Cargo, tons | ← 10 (total) → | 11 | — | — | — | — | — | — |
| Restraint G-factors: | | | | | | | | |
| forward | ← 4 → | 4 | *Floor:* each tie-down 1250 lb vertical and 500 lb horizontal. *Aft bulkhead:* each tie-down 1250 lb parallel to bulkhead and 2195 lb at 45° angle; 2500 lb perpendicular to bulkhead | 12 | 9 | 4 | 8 | 4 |
| aft | ← 2 → | 2 | | 3 | — | 1.5 | 1.5 | 1.5 |
| side | ← 1.5 → | 1.5 | | 8 | 1.5 | 2 | 1.5 | 1.5 |
| vertical (up) | ← 2 → | 2 | | 3 | 3 | 4.5 | 2 | 2 |
| vertical (down) | ← 2 → | 2 | | 3 | 3 | 4.5 | 2 | 2 |

## TABLE 14-4. MAXIMUM PACKAGE SIZE, CH-47C HELICOPTER (A) REAR CARGO DOOR

| WIDTH, in. | HEIGHT, in. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 62 and Under | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 |
| | MAXIMUM LENGTH, in. | | | | | | | | | | | | | | | |
| 62 and Under | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 330 | 282 | 230 | 180 | 135 | 100 | 67 | 30 |
| 63 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 328 | 280 | 228 | 178 | 133 | 98 | 66 | |
| 64 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 326 | 278 | 226 | 176 | 130 | 96 | 64 | |
| 65 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 322 | 274 | 222 | 173 | 127 | 93 | | |
| 66 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 318 | 270 | 218 | 169 | 123 | 90 | | |
| 67 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 313 | 266 | 214 | 165 | 119 | 86 | | |
| 68 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 357 | 307 | 260 | 208 | 160 | 114 | 81 | | |
| 69 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 348 | 299 | 252 | 201 | 154 | 107 | 75 | | |
| 70 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 339 | 290 | 243 | 193 | 146 | 99 | | | |
| 71 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 330 | 281 | 234 | 185 | 139 | 91 | | | |
| 72 | 362 | 362 | 362 | 362 | 362 | 362 | 362 | 321 | 272 | 226 | 177 | 131 | 83 | | | |
| 73 | 362 | 362 | 362 | 362 | 362 | 362 | 352 | 312 | 263 | 216 | 167 | 122 | 75 | | | |
| 74 | 362 | 362 | 362 | 362 | 362 | 362 | 339 | 298 | 250 | 203 | 156 | 112 | | | | |
| 75 | 362 | 362 | 362 | 362 | 362 | 362 | 325 | 284 | 237 | 190 | 144 | 101 | | | | |
| 76 | 362 | 362 | 362 | 362 | 362 | 348 | 311 | 270 | 223 | 177 | 132 | 90 | | | | |
| 77 | 362 | 362 | 362 | 362 | 362 | 334 | 297 | 256 | 209 | 164 | 119 | | | | | |
| 78 | 362 | 362 | 362 | 362 | 346 | 316 | 278 | 237 | 191 | 147 | 104 | | | | | |
| 79 | 362 | 362 | 362 | 362 | 329 | 298 | 258 | 218 | 173 | 129 | 85 | | | | | |
| 80 | 362 | 362 | 362 | 362 | 310 | 276 | 236 | 195 | 151 | 108 | | | | | | |
| 81 | 362 | 362 | 362 | 362 | 289 | 253 | 213 | 172 | 128 | 85 | | | | | | |
| 82 | 362 | 362 | 362 | 362 | 267 | 230 | 188 | 148 | 105 | | | | | | | |
| 83 | 362 | 362 | 362 | 362 | 241 | 202 | 161 | 121 | | | | | | | | |
| 84 | 362 | 362 | 362 | 362 | 213 | 174 | 133 | 93 | | | | | | | | |
| 85 | 362 | 362 | 362 | 362 | 182 | 142 | 100 | | | | | | | | | |
| 86 | 362 | 362 | 362 | 362 | 146 | 105 | | | | | | | | | | |
| 87 | 362 | 362 | 362 | 362 | 105 | | | | | | | | | | | |
| 88 | 362 | 362 | 362 | 362 | | | | | | | | | | | | |
| 89 | 362 | 362 | 362 | 362 | | | | | | | | | | | | |
| 90 | 362 | | | | | | | | | | | | | | | |

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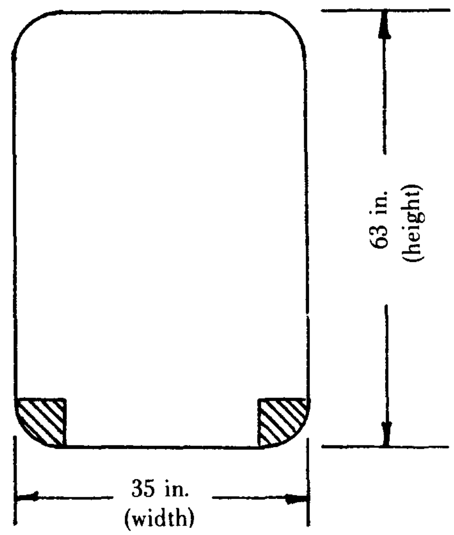
## TABLE 14-4 (cont'd)
## (B) FORWARD DOOR, RIGHT SIDE

| WIDTH, in. | HEIGHT, in. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 53 & Under | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 |
| | MAXIMUM LENGTH, in. | | | | | | | | | |
| 12 | 249 | 246 | 242 | 238 | 234 | 223 | 170 | 170 | 170 | 165 |
| 13 | 233 | 230 | 227 | 224 | 221 | 211 | 162 | 162 | 162 | 157 |
| 14 | 217 | 215 | 213 | 210 | 208 | 199 | 154 | 154 | 154 | 150 |
| 15 | 205 | 204 | 203 | 199 | 197 | 187 | 147 | 147 | 147 | 144 |
| 16 | 195 | 194 | 193 | 189 | 187 | 176 | 141 | 141 | 141 | 138 |
| 17 | 186 | 185 | 183 | 180 | 178 | 166 | 136 | 136 | 136 | 133 |
| 18 | 177 | 176 | 174 | 172 | 170 | 157 | 131 | 131 | 131 | 128 |
| 19 | 169 | 168 | 166 | 164 | 162 | 149 | 126 | 126 | 126 | 124 |
| 20 | 161 | 160 | 159 | 157 | 155 | 142 | 122 | 122 | 122 | 120 |
| 21 | 155 | 154 | 153 | 151 | 148 | 135 | 118 | 118 | 118 | 116 |
| 22 | 149 | 148 | 147 | 145 | 141 | 129 | 114 | 114 | 114 | 112 |
| 23 | 143 | 143 | 142 | 140 | 135 | 124 | 111 | 111 | 111 | 109 |
| 24 | 138 | 138 | 137 | 135 | 129 | 119 | 108 | 108 | 108 | 106 |
| 25 | 133 | 133 | 132 | 130 | 124 | 114 | 105 | 105 | 105 | 103 |
| 26 | 128 | 128 | 127 | 125 | 119 | 110 | 103 | 103 | 103 | 101 |
| 27 | 125 | 124 | 123 | 121 | 115 | 106 | 101 | 101 | 101 | 99 |

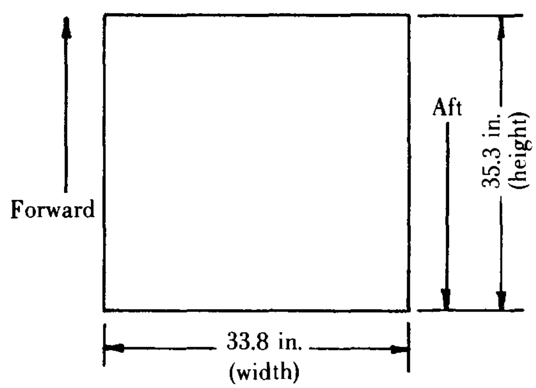



NOTE: Shaded part shows approximate area obstructed by door opening linkage.

## (C) BELLY, UTILITY DOOR

| WIDTH, in. | HEIGHT, in. | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
| | MAXIMUM LENGTH, in. | | | | | | | | | | | | | | | | | | | | | | |
| 33 & Under | 136 | 132 | 128 | 124 | 120 | 116 | 113 | 110 | 107 | 104 | 102 | 100 | 98 | 96 | 94 | 92 | 90 | 88 | 86 | 84 | 82 | 81 | 80 |

**PACKAGES LOADED IN FORWARD DIRECTION**




| WIDTH, in. | HEIGHT, in. | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
| | MAXIMUM LENGTH, in. | | | | | | | | | | | | | | | | | | | | | | |
| 33 & Under | 146 | 140 | 135 | 130 | 126 | 122 | 118 | 114 | 111 | 108 | 105 | 102 | 99 | 96 | 93 | 91 | 89 | 87 | 85 | 83 | 81 | 80 | 79 |

**PACKAGES LOADED IN AFT DIRECTION**

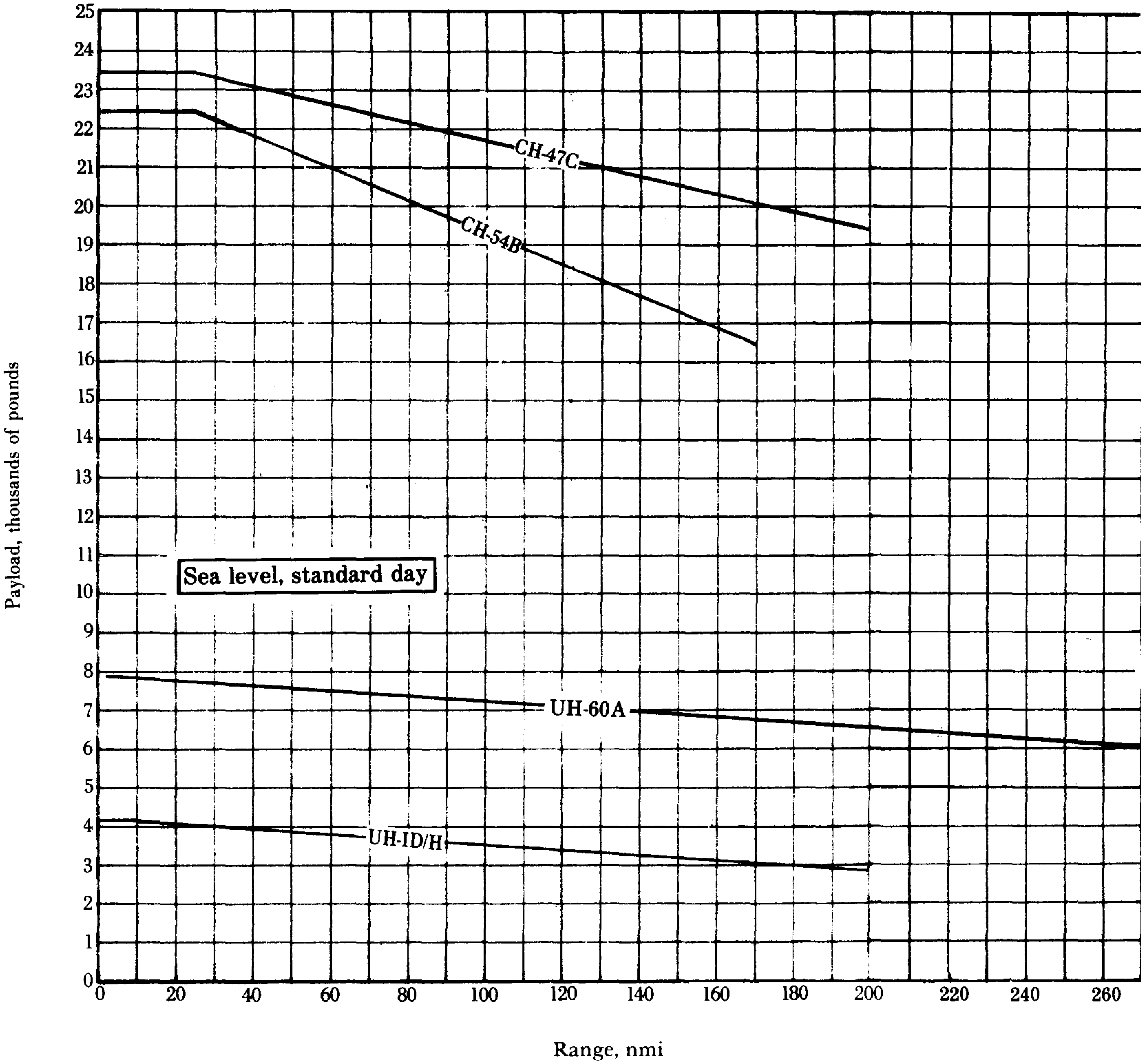


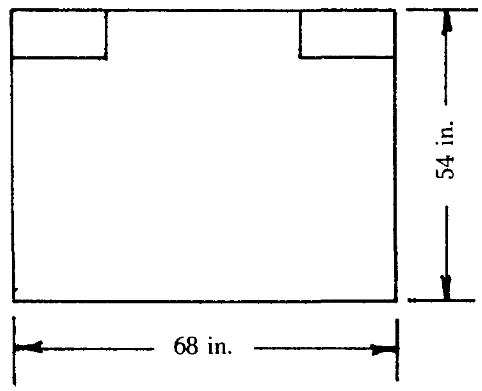

Figure 14-10. Payload vs Range of Army Helicopters

**TABLE 14-5. MAXIMUM PACKAGE SIZE THROUGH CABIN DOORS, UH-60A BLACKHAWK HELICOPTER (UTTAS)**

| WIDTH, in. | HEIGHT, in. | | | | |
|---|---|---|---|---|---|
| | 50 & Under | 51 | 52 | 53 | 54 |
| | MAXIMUM LENGTH, in. | | | | |
| 46 | 102 | 102 | 102 | 96 | 93 |
| 48 | 102 | 102 | 102 | 96 | 93 |
| 50 | 101 | 101 | 101 | 95 | 92 |
| 52 | 100 | 100 | 100 | 94 | 92 |
| 54 | 99 | 99 | 99 | 93 | 91 |
| 56 | 98 | 98 | 98 | 93 | 91 |
| 58 | 97 | 97 | 97 | 93 | 91 |
| 60 | 96 | 96 | 96 | 91 | 90 |
| 62 | 93 | 93 | 93 | 89 | 87 |
| 64 | 91 | 91 | 91 | 87 | |
| 66 | 86 | 86 | 86 | 80 | |
| 68 | 80 | 80 | 80 | 77 | |

NOTE

If gunner's area is not used, lengths are approximately 90% of table values.




**Cabin Door—Both Sides**

**TABLE 14-6. CAPACITIES OF SELECTED COMMERCIAL CARRIER AIRCRAFT**

| | 747F[a] | DC-10[a] | DC-8[a] | 707[a] | L-1011[b] | A-300[c] |
|---|---|---|---|---|---|---|
| Maximum Payload, ton | 90 | 60 | 26-41[d] | 30 | 73 | 45-50[d] |
| Maximum Cargo Volume, $ft^3$ | 22,490 | 16,850 | 6070-8980[d] | 9115-9700[d] | 16,952 | 11,000-12,000[d] |
| Restraint G-factors | | | | | | |
| forward | 1.5 | 1.5 | 1.5 | 1.5 | 0.9 | 1.5 |
| aft | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| vertical | 2.0 | 2.0 | 2.0 | 2.0 | 2.5 | 2.0 |
| lateral | 1.5 | 1.5 | 1.5 | 1.5 | 4.5 | 4.5 |

[a] Data from *Civil Reserve Fleet (CRAF) Load Planning Guide*, Military Airlift Command, Department of the Air Force, 15 Jun 79

[b] Data courtesy of Douglas Aircraft Co., Long Beach, CA

[c] Data courtesy of Airbus Industrie, Blagnac, France

[d] Range is due to various models that exist.

Any load containing a spring in the form of a shock mount or padding must be checked for its natural frequency (see par. 1-13 and Chapter 5). Under no circumstances should the natural frequencies of the system to be carried match the inherent frequencies of the helicopter. Consult the appropriate helicopter Technical Manuals for the information required by Eq. 14-1. Caution should be exercised in selecting spring-mounted loads with frequencies lower than those calculated by Eq. 14-1 since lower frequencies will be excited as the helicopter rotor comes up to speed.

## 14-6 AIRDROP

Containers intended for air delivery must be designed to meet the limitations imposed by the air delivery systems as well as the aircraft employed.

**TABLE 14-7. MAXIMUM PACKAGE SIZE THROUGH 141 in. x 125.5 in. CARGO DOOR, A-300 CARGO AIRCRAFT***

| | HEIGHT, in. | | | | | | |
|---|---|---|---|---|---|---|---|
| WIDTH, in. | 25 and under | 35 | 47 | 61 | 67 | 79 | 88 |
| | MAXIMUM LENGTH, in. | | | | | | |
| 20 | 1086 | 996 | 843 | 677 | 366 | 339 | 268 |
| 40 | 650 | 602 | 541 | 467 | 295 | 276 | 226 |
| 60 | 458 | 435 | 406 | 360 | 248 | 234 | 199 |
| 80 | 356 | 343 | 323 | 293 | 215 | 197 | 159 |
| 100 | 291 | 282 | 270 | 248 | 183 | 173 | 150 |
| 120 | 246 | 240 | 232 | 216 | 165 | 156 | 128 |
| 141 | 206 | 201 | 191 | 176 | 120 | 110 | 79 |

*Data, courtesy of Airbus Industrie, Blagnac, France

The standard air delivery system consists of wheeled conveyors installed on the cargo floor of the aircraft. In order to facilitate rigging procedures of the container to be airdropped, a number of air delivery pallets of various sizes have been developed. There currently are five sizes of pallets—8, 12, 16, 20, and 24 ft in length—each 9 ft wide. The delivery systems are of two types—"end item" in which the parachute is attached to the container and "platform" in which the parachutes are attached to the pallet. (In the near future a single, hybrid system will be deployed to replace the end-item and platform systems.) Each fitting to which a parachute is attached must be designed to withstand a 2.5- to 3-*G* parachute opening force applied in any direction above the horizontal plane. Where hoisting is a requirement for other types of transportation, these fittings must be compatible with the hoisting equipment. A single fitting—for the attachment of the parachute extraction line—should also be provided on each end of the container as close to the vertical and lateral location of the center of gravity as possible. The minimum strength of this fitting should be sufficient to support an ultimate force of three times the filled container weight. Containers employing the platform-type delivery system do not require suspension system fittings for parachute delivery since these are an integral part of the platform.

Deceleration and shock-absorbing devices usually are placed between the platform and the container to aid in cushioning the container when it lands. The expected impact landing velocity and impact force will be 22-28 ft/s and 22-28 *G's*, respectively.

Containers rigged on air delivery pallets must allow a 5-in. lateral clearance and a 6-in. vertical clearance within the aircraft during loading and extraction. The container, when in contact with the pallet, must be no wider than the distance of the outer tie-down rings on the pallet. Refer to the appropriate Army or Air Force Field Manual—e.g., FM 55-13/AFM 76-12 *Air Transport of Supplies and Equipment: Standard Loads in Air Force C-5 Aircraft*—for detailed information on restraints and tie-downs.

# CHAPTER 15
# METAL CORROSION AND MATERIAL DETERIORATION

*The corrosion of metals and the deterioration of other materials of interest—wood, paper, rubber, and plastics—due to various environments are presented. Methods/materials for combating the hostile environments are also presented.*

## 15-1 GENERAL

Corrosion abatement in metals is one of the most important considerations of a new design. Corrosion is closely related to environment, particularly temperature, humidity, and the presence of chemicals. The destructive effects of moisture, chemical action, electrochemical action, and low temperatures and their prevention should be thoroughly investigated. Special attention should be given to the design and finishing of steel containers to eliminate surfaces that are not accessible to finishing. "Hard-to-reach" surfaces should be kept to a minimum and should be corrosion protected in accordance with the general finishing schedule. Internal surfaces of reinforcement conduit and faying surfaces of double construction are sources of corrosion problems. Procedures such as coating the parts prior to assembly, using weld-through primer or continuous welding when the design is a welded assembly, or applying organic sealant are techniques to be considered. The deterioration of other materials related to containers is also important and is discussed.

## 15-2 DETERIORATION OF METAL

### 15-2.1 MOISTURE

Moisture, in the state of water or vapor, accounts for the majority of corroded equipment. Principal locations of moisture are catch basins or sump areas, condensation, and desiccant pumps. A brief discussion of each source follows:

a. Sump Areas: These are areas that normally are exposed to the weather and by improper design allow the accumulation of moisture. This condition is found mainly around the container bases and supports. This condition may be relieved by avoiding angles, channels, pockets, etc., where moisture can accumulate (see Figs. 15-1 and 15-2). When this is unavoidable, drain holes should be provided. In cases where inclosed containers do not lend themselves to drilled holes, the use of desiccants should be employed.

b. Condensation: Moisture will appear inside any closed container that experiences wide temperature changes in relation to the air surrounding it. As was previously mentioned, the amount of moisture may be minimized through the use of desiccants, dehumidification, venting, or drain holes. Drain holes should be located at the lowest possible point.

c. Desiccant Pumps: A desiccant pump is desiccant material that has become saturated with moisture to a point where it can no longer remove moisture from the air. On a day of low relative humidity, the desiccant material is actually a source of moisture. Desiccants therefore should be periodically checked and rejuvenated, or replaced if necessary.

### 15-2.2 GALVANIC CORROSION

With the increasing availability of new materials and alloys, it is most important that designers consider the problems of galvanic (or electrochemical) corrosion in selecting materials. Galvanic corrosion is defined as an electrochemical action between two dissimilar metals, in the presence of an electrolyte, which results in the flow of current. The rate of current flow depends on the potential difference which, in turn, is dependent on the relative dissimilarity of the metals. Table 15-1 lists the electrochemical series along with the relative electromotive potential of the various metals. Table 15-2 lists the relative corrosion resistance of metals in salt water.

Galvanic action results in the progressive corrosion of the more positive (anode) of the two metals, with the action continuing as long as an electrolyte—in our case, water—is present.

In order to minimize corrosion due to electrochemical action, dissimilar metals should not be used in contact with each other. When this is impracticable, the following rules should be followed:

a. Design the anodic member as large as possible.

b. Plate both anodic and cathodic members with identical material.

c. Cadmium plate threaded fasteners and other hardware.

d. Seal threaded inserts with zinc-chromate primer prior to insertion in castings.

e. Do not use dry-film lubricants which are not certified to be graphite-free.

f. When possible, avoid the use of lock washers over plated or anodized surfaces.

TABLE 15-1
ELECTROMOTIVE FORCE SERIES

| Metal | | Potential, V |
|---|---|---|
| | Anodic (Positive) End | |
| Lithium | | - 2.959 |
| Rubidium | | - 2.925 |
| Potassium | | - 2.924 |
| Calcium | | - 2.76 |
| Sodium | | - 2.714 |
| Magnesium | | - 1.8 |
| Aluminum | | - 1.337 |
| Zinc | | - 0.761 |
| Chromium | | - 0.557 |
| Iron (ferrous) | | - 0.44 |
| Cadmium | | - 0.401 |
| Cobalt | | - 0.23 |
| Nickel | | - 0.20 |
| Tin | | - 0.136 |
| Lead | | - 0.122 |
| Hydrogen | neutral | 0.00 |
| Copper | + | +0.344 |
| Silver | | +0.797 |
| Platinum | | +0.86 |
| Graphite | | --- |
| Gold | | +1.36 |
| | Cathodic (Negative) End | |

### 15-2.3 CHEMICALS

Corrosion of metals by reaction with chemical substances in the environment occurs under a variety of circumstances. Most chemical attacks depend on moisture to be effective.

Salts are particularly high in corrosive chemicals. Free acids and alkalies are encountered in airborne contaminants and in large concentrations in soil and natural waters. Salt spray will be encountered near the ocean and aboard ship. Table 15-2 lists the galvanic series for a variety of metals and alloys in sea water.

Salts that are in the soil and water are the most widely distributed and troublesome of the corrosive chemicals. The natural salts causing the most trouble are the chlorides, nitrates, sulfates, phosphates, and carbonates.

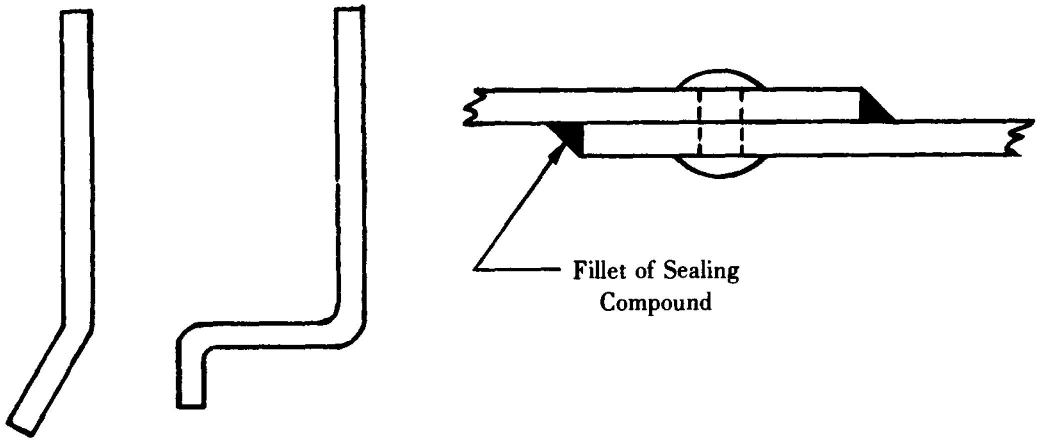
When salts are in solution or in a moist environment, they hydrolize, forming acids and bases. What effect salts will have upon a metal depends on the chemical and electrochemical relationship between them. Iron and steels are primarily affected by sodium chloride salt spray. Aluminum is relatively immune to sodium chloride spray, but is readily attacked by the salts of strong bases and weak acids—e.g., the sodium, potassium, and ammonium salts of acetic, oxalic, and tartaric acids.

Acids and alkalies are rarely encountered in natural environments with the exception of the high acid

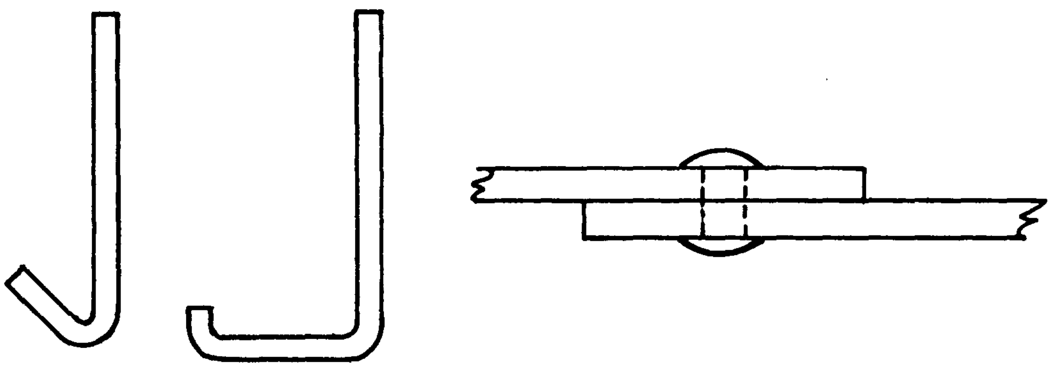
TABLE 15-2
GALVANIC SERIES IN SEA WATER

1. Magnesium
2. Magnesium alloys
3. Zinc
4. Galvanized steel
5. Aluminum (52SH, 61S, 3S, 2S, 53ST in this order)
6. Aluminum clad, 24ST, 17ST
7. Cadmium
8. Aluminum (75ST, A17ST, 17ST, 24ST in this order)
9. Mild steel
10. Wrought iron
11. Cast iron
12. Ni-Resist
13. 13% chromium stainless steel, type 410 (active)
14. 50-50 lead-tin solder
15. 18-8 stainless steel, type 304 (active)
16. 18-8-3 stainless steel, type 316 (active)
17. Lead
18. Tin
19. Muntz metal
20. Manganese bronze
21. Naval brass
22. Nickel (active)
23. Inconel (active)
24. Yellow brass
25. Admiralty brass
26. Aluminum bronze
27. Red brass
28. Copper
29. Silicon bronze
30. Ambrac
31. 70-30 copper nickel
32. Comp. G-bronze
33. Comp. M-bronze
34. Nickel (passive)
35. Inconel (passive)
36. Monel
37. 18-8 stainless steel, type 396 (passive)
38. 18-8-3 stainless steel, type 316 (passive)

(No. 1 is the most corrosive.)




(A) Acceptable Design Features



(B) Unacceptable Design Features

**Figure 15-1. Design Features for Corrosion Prevention**

concentration found in airborne contaminants. The worst offenders of this category are found in industrial gasses in the form of sulfurous acid and carbonic acid. These acids are formed from sulfur dioxide and carbon dioxide in the presence of water. Acid rains with pH as low as 3.3 are not uncommon in industrial areas.

Carbonic acid is classified as a fairly weak acid, resulting in minimal deterioration. Sulfurous acid, on the other hand, is a very strong acid which may be oxidized under suitable conditions to form the more powerful sulfuric acid. Both of these acids are extremely corrosive toward iron, steel, copper, and zinc compounds and, to some extent, aluminum. Hydrogen sulfide is another sulfur compound frequently found in industrial gasses and, in the presence of moisture, presents a corrosive effect. This effect, however, is limited primarily to steel.

### 15-2.4 TEMPERATURE

It is a well-known fact that as the temperature decreases, metals become more brittle. This change in the property of metals makes them more suscepti-

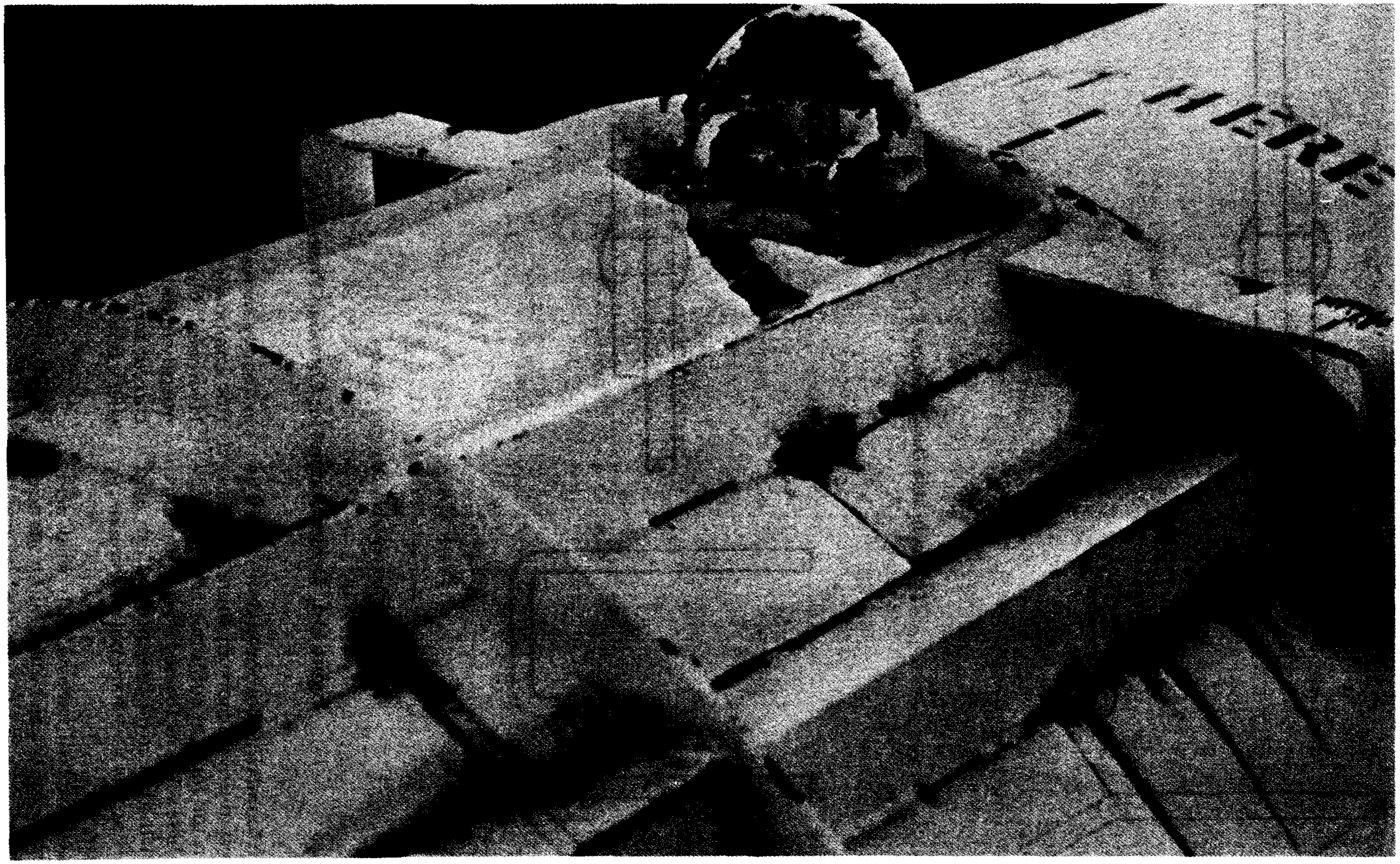


**Figure 15-2. Water Pockets Due to Inadequate Drainage Provisions**

ble to failure in areas of high stress concentration. Some of these transition temperatures occur at relatively high temperatures, i.e., steels that are not thoroughly deoxidized will have their transition temperature at approximately 32°F.

Although this brittle phenomenon cannot be prevented, the designer should be aware of this property of metals and design accordingly. Some methods of overcoming this problem may be to add a sufficient safety factor or recommend that certain metals or certain manufacturing processes not be employed for cold temperature use.

### 15-2.5 FILIFORM CORROSION

Filiform corrosion is a galvanic corrosion occurring under painted surfaces. Its form is a radial "worm-like" corrosion path emanating from the central core of the corrosion. It occurs under paint, plating, or gaskets, due to the permeability of these coatings to moisture. The humidity level determines the degree of corrosion, and the temperature determines the rate and path of corrosion. Filiform corrosion will only occur between 78% and 85% relative humidity.

Lacquers and "quick-dry" paint are most susceptible to damage. A heavy, phosphate (Parkerized) coating eliminates filiform corrosion. Epoxy coatings with excellent adhesion and low water transmission are also good.

### 15-2.6 HYDROGEN EMBRITTLEMENT

Plated, high-carbon materials absorb hydrogen in grain boundaries, causing embrittlement of the part. The higher the stress in a part, the more susceptible it is to embrittlement failure.

It is recommended that the part be stress-relieved (25 to 50 deg F below the draw temperature) prior to plating.

Hydrogen embrittlement occurs in welded assemblies, and in springs where it is recommended that they be stress relieved immediately after the coiling operation. A 450°F oven is recommended.

### 15-2.7 FINISHES

The life of metals can be increased through the use of corrosion-resistant coatings of metal, paint, and plastic, and by surface treatment of the metal with semipermanent corrosion preventive materials. Each process is discussed briefly.

#### 15-2.7.1 Metal Coatings

Steel is usually protected against corrosion by a corrosion-resistant metal coating. Cadmium, zinc, nickel, chromium, tin, and lead are the metals most frequently used for this purpose. All of these metals can be electroplated onto steel; zinc, tin, and lead also can be applied by hot dip.

Aluminum uses two major finishes, namely: (a) electrochemical conversion (MIL-A-8625), and (b) chemical conversion (MIL-C-5541), oxide coatings. A discussion follows:

a. Electrochemical Conversion:

The electrochemical conversion finishes can be classified into three different processes: (1) sulfuric acid anodize, (2) chromic acid anodize, and (3) aluminum oxide hardcoats. Each process is discussed:

(1) Sulfuric Acid Anodize:

This is the most economical process in anodizing aluminum. The coating varies from a clear, transparent film to one that is opaque or translucent. All welding and fabrication should be accomplished prior to anodizing, and caution should be exercised to insure that all the sulfuric acid electrolyte is bled from the pores, joints, and recesses. Where trapped electrolyte could be a problem, chromic acid anodizing is recommended. Dimensional changes are in the order of 0.0002 in. The main advantages of sulfuric acid anodize are:

(a) Provides good corrosion resistance and paint base qualities
(b) Good abrasion resistance
(c) Excellent heat resistance
(d) Good dielectric strength
(e) Better absorption qualities than other processes
(f) Lower voltages required than in other processes.

The disadvantages of this process are:

(a) Should not be used where electrolyte may become entrapped in pores, joints, or recesses
(b) Welds become conspicuous.

(2) Chromic Acid Anodize:

The coatings produced from this process are opaque and grey in color. This process should be used on porous castings and aluminum assemblies with joints or recesses where the electrolyte may become entrapped. The advantages of this process are:

(a) Good corrosion resistance properties
(b) Excellent heat resistance
(c) Good dielectric strength. This can be improved by saturating the coating with oil, grease, wax, or other appropriate materials.

The main disadvantage of chromic acid anodize is that it cannot be used on aluminum alloys of more than 5% copper or a total alloy of more than 7.5%.

(3) Aluminum Oxide Hardcoat Processes:

This process forms an oxide coating of various shades of grey or black. Coating thicknesses range from 0.002 in. to 0.005 in. of which approximately one-half of the thickness is buildup, the remainder being penetration. Corners must maintain a generous radius (Fig. 15-3 (B)) or an easily damaged corner will be formed as shown in Fig. 15-3(A). The major advantages of this process are:

(a) Excellent wear and abrasion resistance

(b) Excellent insulating properties

(c) Can be used to eliminate dissimilar metal inserts in aluminum where a hard wearing surface is required.

The disadvantages of aluminum oxide hardcoat processes are:

(a) Dimensional build is heavy and must be considered during design.

(b) Coatings are too hard to be machined and must be ground when close tolerances are required.

(c) Process cannot be applied when aluminum alloys contain more than 5% copper or 7% silicon.

(d) Fatigue strength of some alloys is lowered considerably.

(e) Coatings will not form around sharp corners.

b. Chemical Conversion:

The chemical conversion group of oxide coatings forms an oxide film on the material which is thinner, softer, and more porous than coatings formed by anodizing. This process may be used as a paint base under most conditions, but exhibits low abrasion resistance and little corrosion resistance when exposed directly to the atmosphere. Chemical conversion coatings have low bond strength to the base material and, therefore, cannot be used for adhesive bonding with epoxy paints. Chemical conversion coatings are nonconductive.

### 15-2.7.2 Paint

Paint prevents corrosion by protecting a metal surface from moisture. There are also corrosion-inhibiting primers which can be applied to a metal surface prior to painting. These primers are intended primarily for metals and are used where more severe environmental conditions, such as salt spray and other chemical-laden fluids, are present. These primers usually consist of a liquid vehicle or binder and a corrosion-inhibiting pigment such as red lead or zinc yellow. The lighter zinc pigments should be used where weight is a factor.

### 15-2.7.3 Plastic Coatings

Protective plastic coatings consist of solutions or dispersions of film-forming plastics in organic solvents or may be applied as a dry, solid powder by various techniques. These coatings are satisfactory for continuous contact with mild corrosives such as fresh and salt water, some solvents, and some alkalies. Plastic materials, employed as protective coatings, are of two basic types: thermoplastic and thermosetting.

The thermoplastic coatings most widely used are polyethylene, styrene copolymers, polyvinyl chloride resins, and the fluorocarbons. Several of the thermosetting types of plastics being used for corrosion-resistant coatings are polyesters, epoxies, vinyl esters, polyurethanes, and phenolics.

### 15-2.7.4 Vapor Corrosion Inhibitor (VCI)

VCI is a vaporizing type of chemical inhibitor used for corrosion control in sealed areas. The inhibitor (dicyclohexylamine nitrite) is available both as a treated paper, MIL-P-3420, or as two viscosity oils: Grade 1, light viscosity oil, and Grade 2, medium viscosity oil.. Grade 1 oil is for rapid, short-lived protection, and Grade 2 oil is for slower but longer-lived protection. Their application in a sealed volume is necessary in order for the vapors to be effective as a preservative.

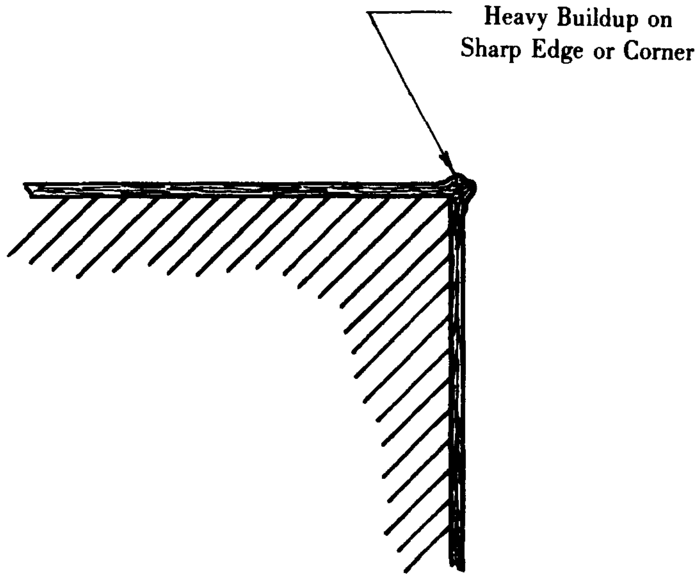
VCI is intended primarily for corrosion protection of steel; however, it is usable with cadmium, magnesium, or zinc if the proper grade is used for these materials. When the oil is used, it is so prepared that it has no harmful effects on cadmium, zinc, magnesium, or aluminum.

The compound VCI is unstable at temperatures higher than 150°F, or in atmospheres of high humidity. For details on the use of VCI, consult TM 38-230-1, *Packaging of Materiel, Preservation, Vol. 1.*

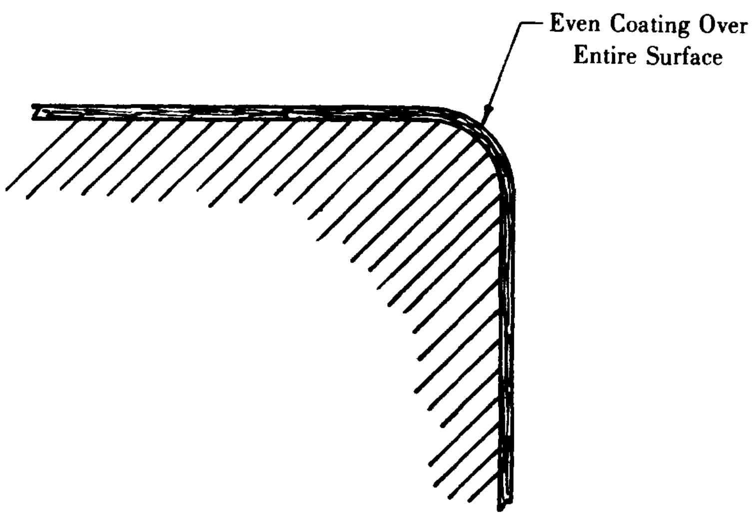
## 15-3 DETERIORATION OF WOOD*

Wood is susceptible to deterioration from the effects of climate, physical forces, chemical agents, microorganisms, and insects. A brief discussion of the effects of these causative agents follows.

*For a more thorough discussion of deterioration refer to Engineering Design Handbook, AMCP 706-121, *Packaging and Pack Engineering.*




(A) Plated Part with Sharp Edge




(B) Plated Part with Rounded Edge

**Figure 15-3. Design for Preventing Damaged Corners**

### 15-3.1 MICROORGANISMS †

The growth of most microorganisms occurs most rapidly during warm, humid weather. Wood, in contact with the ground, is especially susceptible to fungi and molds. Most of these organisms cause decay with a resulting decrease in strength, while others attack plywood glues. Protection against microorganisms in wood can be obtained by the use of wood preservatives. Some of the preservatives are poisonous to the attacking organisms and some act only as repellants. Others form a physical barrier that prevents the organisms from entering the wood.

Items shipped to areas where optimal conditions for decay are prevalent should use decay-resistant woods or some type of decay-treated woods. Table 15-3 lists the decay resistance of some woods.

TABLE 15-3
HEARTWOOD DECAY RESISTANCE OF SOME WOODS COMMON IN THE U.S.[a]

| Good | Fair | Poor |
|---|---|---|
| Bald Cypress | Douglas Fir | Ashes[b] |
| Catalpas | Honey-locust[b] | Aspens |
| Cedars | Larch, western | Basswood |
| Chestnut | Oak, chestnut | Beech[b] |
| Junipers | Oak, white | Birches[b] |
| Locust, black | Pine, eastern white | Cottonwood |
| Mesquite | Pine, southern yellow | Firs (true) |
| Mulberry, red | Sassafras | Hemlocks |
| Osage-orange | | Maple, sugar[b] |
| Redwood | | Oak, northern red[b] |
| Walnut, black | | Spruces[b] |
| Yew, Pacific | | Willows |

[a]The species in each group are listed alphabetically, it being impractical to list them in order of relative decay resistance.

[b]These species may rate nearly as high in decay resistance as some of those in the next better group.

† For a more thorough discussion of the effects of microorganisms and insects refer to Engineering Design Handbook, AMCP 706-116, *Environmental Series, Part Two, Natural Environmental Factors.*

Wood preservatives may have either an oil base or a water base. Oil-based preservatives will not be washed away or leached out by water, and they make the wood moisture-repellant. Water-based preservatives are cheaper than oil-based preservatives, which is their primary advantage. Table 15-4 lists some wood preservatives.

### 15-3.2 INSECTS †

Wood is subject to attack by insects even when it is supported above the ground and kept dry. Damage to wood in contact with the ground is due primarily to termites and powder-post beetles, while damage to wood supported above the ground is due primarily to powder-post beetles and dry-wood termites.

The wood preservatives used to protect against microorganisms are also effective in combating insect infestation. The surface of the wood should be coated with a thin film, to prevent the deposition of eggs in the wood pores.

### 15-3.3 PHYSICAL AGENTS

Wood is also susceptible to deterioration from such physical agents as abrasion, weathering, and high temperatures. Abrasion usually occurs during shipment and handling; accordingly, a hard, abrasion-resistant wood should be used for this purpose. Reinforcement in the areas where excessive wear occurs also should be used if possible.

Unfinished wood exposed to alternate periods of rainfall and hot, dry weather produces cracks, splits, and general erosion of wood, and eventually, a severe loss of strength. High temperatures also cause loss of strength with the rate of loss increasing with temperature.

Fig. 15-4 shows the effect of weathering on two different types of plywood. The type on the left is an exterior plywood and shows no effect from weathering. The plywood on the right is an interior type of plywood and, as can be seen, the laminations have started to warp and separate.

### 15-3.4 CHEMICALS

Chemicals can readily destroy or weaken wood and wood products. Some woods are resistant to certain chemicals and should therefore be used where contact with these chemicals is contemplated.

**TABLE 15-4**
**WOOD PRESERVATIVES**

| Oil Base | Water Base |
|---|---|
| Coal-Tar Creosotes | Cupric Chromate ("Celcure") |
| Creosote-Coal Tar Solution | Chemonite |
| Creosote-Petroleum Solution | Chromated Zinc Chloride |
| Wood-Tar Creosote | "Wolman" Salt Tanalith |
| Lignite-Tar Oil | Zinc Chloride |
| Copper Naphthalate | Zinc Metaarsenite |
| Pentachlorophenol | "Greensalt" |
| Zinc Naphthalate | "Erdalith" |
| | "Boliden Salt" |
| | "Minalith" |
| | "Pyresote" |
| | CZC (FR) |

## 15-4 DETERIORATION OF PAPER*

Paper products usually consist of wood derivatives and, therefore, are subject to many of the deteriorating agents affecting wood.

### 15-4.1 MICROORGANISMS

Microorganisms are also a serious threat to paper, paperboard, and fiberboard. Mildew, bacteria, and fungi are the chief offenders. Treatment of these products with fungicides and mold-inhibiting solutions is the accepted preventive measure. Compounds used for treating paper are listed in Table 15-5.

### 15-4.2 MOISTURE

One of the ways moisture can cause deterioration of paper is by dissolving or softening the gelatinous binder used to hold the fiber together. This causes the paper to lose its structural strength and eventually fall to shreds. Where moisture is expected to be a problem, wet-strength papers should be specified.

Moisture also makes paper inhabitable for the growth of microorganisms which cause decay.

### 15-4.3 INSECTS

Some insects use paper as a food, thereby causing structural damage. Termites consume paper for its prime structural component, cellulose; whereas silverfish destroy paper by eating the starchy material, such as glue and sizing. Cockroaches feed on many materials, eating bindings and paper. Termites and cockroaches will attack sheet paper, pasteboard, composition board, fiberboard, labels, paper boxes, insulating paper, and tar paper. The time required for insects to penetrate various paper products is given in Table 15-6.

An effective means of controlling insects is to incorporate insecticides in the material and to spray around storage areas. Table 15-7 lists some insecticides used for this purpose.

### 15-4.4 RODENTS

Rodents damage paper products in their gnawing for food. Since these paper particles are not swallowed, toxic agents are useless. The only really effective preventive is to set out poisoned bait. The generalized effects of some deleterious agents are shown in Table 15-8.

### 15-4.5 CHEMICALS

Deterioration of paper from chemicals is another area that must be considered when using paper products. In industrial atmospheres, the greatest hazard is from the sulfur dioxide gas present. This gas forms acids that attack the gel-like portion of the fibers and, to a certain extent, the cellulose content. Deterioration varies according to the type of paper—highly purified wood fiber papers are least affected.

### 15-4.6 TEMPERATURE

High temperatures can weaken paper by altering its chemical structure. Heat also provides an ideal environment for decay caused by microorganisms and moisture.

*For a more thorough discussion of deterioration refer to Engineering Design Handbooks: AMCP 706-116, *Environmental Series, Part Two, Natural Environmental Factors; and AMCP 706-121, Packaging and Pack Engineering.*

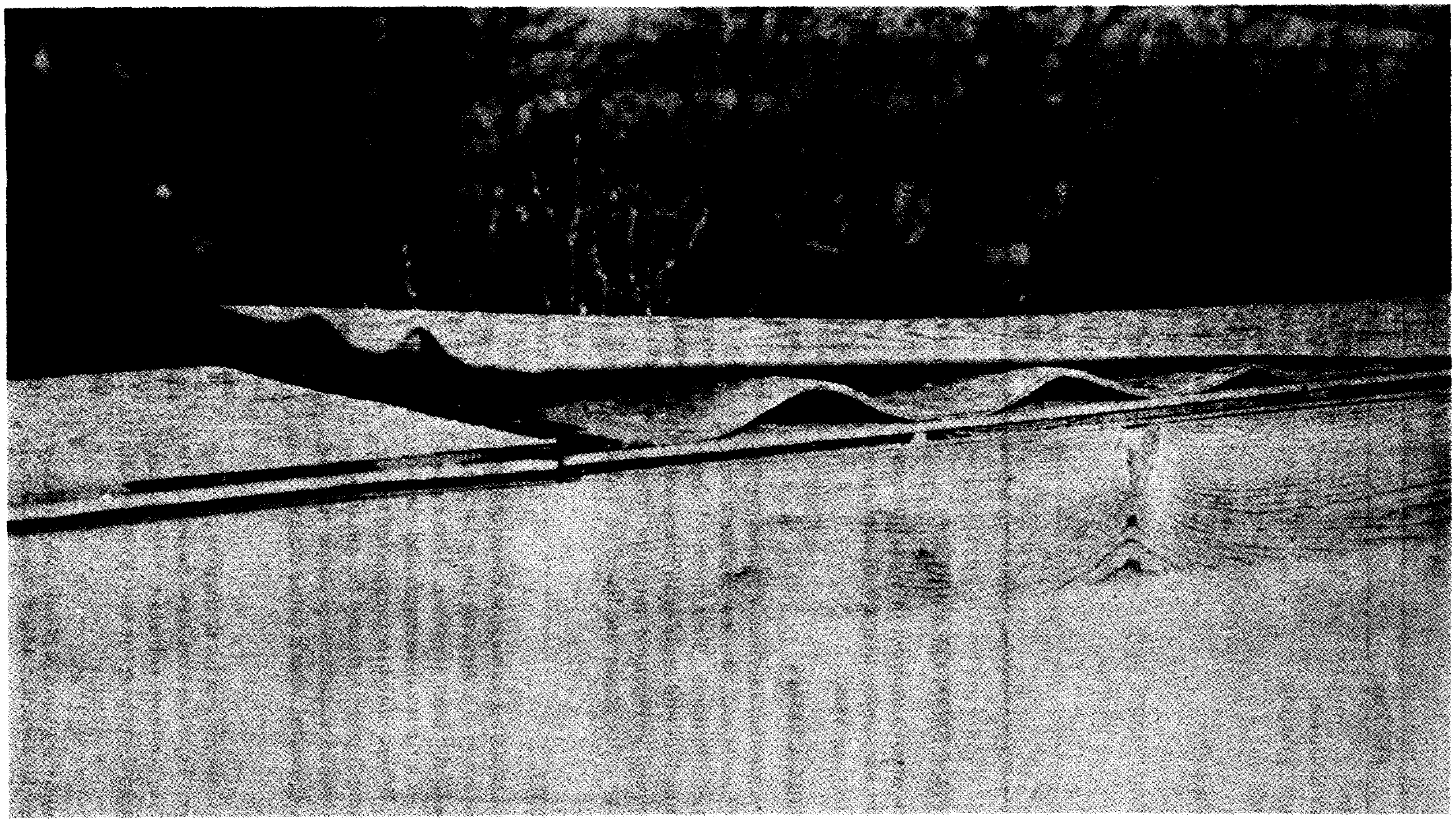


Figure 15-4. Effect of Weathering on Plywood (Exterior type is on left; interior type on right.)

**TABLE 15-5**
**TREATMENT OF PAPER FOR MICROORGANISMS**

| Treating Method or Compound Used | Treating Method or Compound Used |
|---|---|
| Acetone | Mercuric benzoate |
| Acetylation | Mercuric chloride |
| Asphalt | Mercuric salicylate |
| Benzoates | Mercurophen |
| Benzoic acid | 2, 2'-Methylenebis (4-chlorophenol) |
| Benzoic acid, sodium-o-ethylmercuri mercapto | Microcrystalline wax |
| Betanaphthol | p-Nitrophenol |
| Bismuth benzoate | Paraffin |
| Borates | Pentachlorophenol or its sodium salt |
| Boric acid | Phenylmercury acetate |
| Bromobenzene, mono | Phenylmercury acetate plus calcium carbonate |
| Bromoform | Phenylmercury acetoxy octadecanoic acid |
| Calcium propionate | Phenylmercury oleate |
| Carbon disulfide | Phenylmercury saccharinate |
| Chloramine-T | o-Phenylphenol |
| Chlorobenzene, mono | Phenyl salicylate |
| Chlorocarvacrol | Polyester treatment |
| Chloroform | Quinoline, 8-hydroxy |
| Chloronaphthalene | Salicylanilide |
| Chlorophenol salts | Salicylic acid |
| Chlorothymol | Silico fluoride, sodium |
| Chloroxylenols | Styrene |
| Copper naphthenate | Tetrachloroethane |
| Copper oleate | Tetrachlorophenol, sodium salt |
| Copper-8-quinolinolate | Toluol |
| Copper resinate | Tribromonaphthol |
| Copper sulfate | Trichlorophenol |
| m-Cresol, p-chloro- | Vinyl treatment |
| o-Cresol | Xylol |
| Creosote with copper oleate | Zinc chloride |
| Cuprammonium process | Zinc dimethyldithiocarbamate |
| Dichlorodimethyl succinate | Zinc naphthenate |
| Formaldehyde | Zinc oleate |
| GR-S rubber | Zinc resinate |
| Hexylresorcinol | Zinc sulfate |
| Hydrogen sulfide | |

## 15-4.7 SUNLIGHT

Continued exposure to sunlight causes deterioration of the main structural component of paper, i.e., cellulose. The rate and severity of deterioration is dependent upon the kind of cellulose used in the paper and the impurities present in the cellulose. Deterioration by sunlight is a minor problem for paper used as packaging material.

**TABLE 15-6**
**TIME REQUIRED BY CERTAIN INSECTS TO PENETRATE VARIOUS PAPERS AND OTHER BAG MATERIALS**

| Material[a] | Common Dampwood Termites | Nevada Dampwood Termites |
|---|---|---|
| Toweling | 3.5 h | 3 h |
| Asphalt bagging | 7 days | 8 days |
| Cellophane No. 300 | 4 days | 5 days |
| 50-lb kraft paper | 1 day | 1 day |
| 50-lb kraft paper plus 50% sodium silicate solution | 5 days | 6 days |
| 3/0 flint sandpaper[b] | more than 35 days | more than 35 days |
| 3/0 flint sandpaper[c] | 14 days | 14 days |
| Cellophane No. 300 on 0.0006-in. lead foil[d] | more than 35 days | more than 35 days |
| No. 30 sulfite paper on 0.00035-in. lead foil[e] | 10 days | 10 days |
| 0.00035-in. lead foil on No. 30 sulfite paper[d] | more than 35 days | more than 35 days |

Notes:
[a]Thickness, 0.00088 in.
[b]Rough side up
[c]Smooth side up
[d]Foil side up
[e]Paper side up

**TABLE 15-7. INSECTICIDES***

| Compound | Effective Against: Cockroaches | Silverfish | Termites |
|---|---|---|---|
| Chlordane | x | | x |
| Diazinon | x | x | |
| Dichlorvos | x | x | |
| Dieldrin | | | x |
| Dursban | x | | |
| Fenthion | x | | |
| Lindane | | | x |
| Malathion | x | x | |
| Methyl bromide | | | x |
| Pentachlorophenol | | | x |
| Propoxur | x | | |
| Sulfuryl fluoride | | | x |

*Some of these insecticides may be banned because of toxicity to man.

**TABLE 15-8**
**TOXIC RODENT BAITS AND THEIR GENERAL EFFECTIVENESS***

| Faster-Killing Poisons: | Stronger Poisons: |
|---|---|
| Strychnine sulfate | Strychnine sulfate |
| Strychnine alkaloid | Strychnine alkaloid |
| Sodium fluoroacetate | Phosphorus paste |
| | Zinc phosphide |
| | White arsenic |
| | Thallium sulfate |
| | ANTU |
| | Sodium fluoroacetate (Compound 1080) |
| | Warfarin |
| Slower-Killing Poisons: | Weaker Poisons: |
| Red squill | Barium carbonate |
| Thalium sulfate | Red squill |

*Some of these chemicals may be banned because of toxicity to man.

**TABLE 15-9**
**PHYSICAL PROPERTIES OF SYNTHETIC AND NATURAL RUBBERS**

| Material | Effect of Heat | Abrasion Resistance | Effect of Sunlight (under tension) | Effect of Aging |
|---|---|---|---|---|
| Chemigum, oil-resistant | Stiffens | Excellent | Equal to rubber | Stiffens |
| Chemigum, tire | Stiffens | Good | None | Better than rubber |
| GR-I (Butyl) | Stiffens slightly | Excellent | None | Highly resistant |
| GR-M (Neoprene) | Stiffens slightly | Excellent | None | Highly resistant |
| GR-N (Perbunan) | Stiffens | Excellent | Slight | Highly resistant |
| GR-P (Thiokol FA) | Hardens slightly | Fairly good | None | None |
| GR-P (Thiokol ST) | Hardens slightly | Good | None | None |
| GR-S (Buna S), hard | — | — | — | Highly resistant |
| GR-S (Buna S), soft | Stiffens | Excellent | Deteriorates | Highly resistant |
| Hycar OR-15, soft | Stiffens | Excellent | Slightly better than natural rubber | Highly resistant |
| Hycar OR-25, soft | Stiffens | Excellent | Slightly better than natural rubber | Highly resistant |
| Hycar OR-15, hard | — | — | — | Highly resistant |
| Hycar OR-10, soft | Stiffens | Excellent | Deteriorates | Highly resistant |
| Koroseal, soft | Softens | Good | None | Highly resistant |
| Koroseal, hard | Softens | Excellent | None | Highly resistant |
| Pliolite, No. 40 | Softens | — | None | None |
| Resistoflex | Softens | Good | None | None |
| Tygon T | Softens | Good | None | — |
| Vistanex, medium | — | — | None | Better than rubber |
| Vistanex, high | — | — | None | Better than rubber |
| Natural rubber, hard | — | — | — | Highly resistant |
| Natural rubber, soft | Softens | Excellent | Deteriorates | Moderately resistant |

TABLE 15-10
RESISTANCE OF NATURAL AND SYNTHETIC RUBBERS TO MICROORGANISMS

| Material | Resistance |
|---|---|
| Natural rubber | |
| Pure natural rubber—caoutchouc | Attacked |
| Highly purified natural rubber, 99%+, not vulcanized | Attacked |
| Natural rubber vulcanizate | Attacked |
| | Resistant |
| Hevea latex | Attacked |
| Guayule latex | Attacked |
| Crude sheet | Attacked |
| Crepe rubber | Attacked |
| Pale crepe, not compounded | Attacked |
| Pale crepe, compounded | Resistant |
| | Attacked |
| Plantation crepe | Attacked |
| Smoked sheet, not compounded | Attacked |
| Smoked sheet, compounded | Resistant |
| | Attacked |
| Reclaimed rubber | Attacked |
| Gutta-percha | Some attack but less than natural rubber |
| Chlorinated rubber | Resistant |
| Synthetic rubbers | |
| Neoprene-polychloroprene, not compounded | Resistant |
| | Attacked |
| Neoprene, compounded[a] | Resistant |
| | Attacked |
| GR-S, butadiene-styrene, not compounded | Resistant |
| | Attacked |
| GR-S, butadiene-styrene, compounded[b] | Resistant |
| | Attacked |
| GR-S, butadiene-styrene, compounded, acetone extracted | Resistant |
| Buna-S, butadiene-styrene, uncured | Attacked |
| "Hycar OR", butadiene-acrylonitrile, not compounded | Attacked |
| "Hycar OR", butadiene-acrylonitrile, compounded | Resistant |
| | Attacked |
| Buna N, butadiene-acrylonitrile, compounded | Attacked |
| GR-I (butyl), isobutylene-isoprene, uncured | Resistant |
| | Attacked |
| GR-I (butyl), isobutylene-isoprene, compounded | Resistant |
| | Attacked |
| "Thiokol", organic polysulfide, uncured | Attacked |
| "Thiokol", organic polysulfide, vulcanized | Resistant |
| "Thiokol", organic polysulfide, sheets for gasoline tank linings | Attacked |
| Silicon rubber | Resistant |
| Elastomers from: | |
| Butadiene | Attacked |
| Isoprene | Attacked |
| Isobutylene | Attacked |
| Acrylonitrile | Attacked |
| Styrene | Attacked |

[a]Neoprene containing nutrients may be attacked, but the hydrocarbon itself is not attacked.

[b]Produced by improved processing to give resistance to fungi.

## 15-5 DETERIORATION OF RUBBER*

Rubber is subject to deterioration by a variety of chemical, biological, and physical agents—working individually or in combinations. The degrading effects of some of these agents are listed in Table 15-9.

### 15-5.1 MICROORGANISMS

Certain rubber compounds are susceptible to microbiological deterioration. Deterioration is fairly slow and requires a warm, moist environment. Table 15-10 gives the resistance of several rubbers against attack by microorganisms.

### 15-5.2 CHEMICALS

The most serious cause of deterioration in rubber is caused by the ozone present in the atmosphere. Ozone causes rubber to become brittle and may produce fissures over its surface. The severity of attack varies greatly according to the type of rubber. Oxygen has similar effects but they are subordinate in importance to those caused by ozone. Neoprene, butyl, Thiokol, silicone, Hypalon, and polyacrylate rubbers are more resistant to ozone than polymers based on butadiene or isoprene—such as GR-S, nitrile rubber, or natural rubbers.

Natural rubbers swell when in contact with liquid hydrocarbons such as oil, gasoline, and benzene. Disintegration and aging occur from prolonged contact. Several synthetic rubbers have been developed which are oil-resistant; these products are substituted for natural rubbers when contact with oil or chemicals is expected. Neoprene, Thiokol, butadiene-acrylonitrile vulcanizates, some polyacrylic ester compounds, and chlorinated rubber often are used for these purposes.

### 15-5.3 TEMPERATURE

A number of changes take place in rubbers, particularly carbon-based types, under the influence of low temperatures. All of these changes are reversible however, and the material recovers its original properties as temperatures return to normal. As the temperature is decreased, the rubber becomes more difficult to bend or stretch. Below a certain subzero temperature, this stiffness increases to a maximum, at which the rubber becomes brittle and will shatter under suddenly applied loads. Long-time exposure is sometimes accompanied by crystallization and the plasticizer-time effect. Crystallization results in an increase in stiffness but not necessarily in brittleness. In the plasticizer-time effect, the plasticizer is thrown out of solution, which may result in a loss of flexibility above the brittle temperature and also causes the temperature at which embrittlement takes place to rise. The various commercial rubbers differ appreciably as to the temperature ranges in which they pass through these various stages.

At high temperatures, both natural and synthetic rubbers become gummy, take on a permanent set, and decrease in tensile strength. The temperatures at which various types of rubber become unusable are shown in Table 15-11. The more general effects of heating are included in Table 15-9.

### 15-5.4 SUNLIGHT

Decomposition of rubber by sunlight is due mainly to the blue and ultraviolet wavelengths. These rays cause the rubber to liberate gasses as the rubber decomposes. The surface of rubber, undergoing solar deterioration, exhibits resinification of the surface and an irregular pattern of very fine cracks. The effects of sunlight on various rubbers are included in Table 15-9.

Preventive measures include coloring the rubber to decrease the effect of the damaging wavelengths, although storage in darkness is the most effective measure.

**TABLE 15-11**
**DEGRADATION OF RUBBER BY HIGH TEMPERATURES**

| Type of Rubber | Highest Usable Temperature, °F (°C) |
|---|---|
| Silicone | 500 (260) |
| Polyacrylic | 350 (177) |
| Buna—N | 340 (171) |
| Neoprene | 315 (157) |
| Butyl | 300 (149) |
| Buna-S | 280 (138) |
| Natural | 260 (127) |
| Thiokol | 250 (121) |

*For a more thorough discussion of deterioration refer to Engineering Design Handbook, AMCP 706-121, *Packaging and Pack Engineering.*

TABLE 15-12
RESISTANCE OF PLASTICS TO ATTACK BY MICROORGANISMS

| Material | Resistance |
|---|---|
| Phenol-formaldehydes | |
| Phenol-formaldehyde[a] | Good |
| Phenol-aniline-formaldehyde | Poor |
| Resorcinol-formaldehyde | Good |
| Urea-formaldehydes | |
| Urea-formaldehyde[b] | Good |
| Protein-formaldehydes | |
| Zein-formaldehyde ("Vicara") | Good |
| Casein-formaldehyde | Poor |
| Polyamides | |
| Nylon[c] | Good |
| Polyesters | |
| Ethylene glycol terephthalate ("Terylene") ("Fiber V") | Good |
| Polyethylenes | |
| Polyethylene[d] | Good |
| Polytetrafluoroethylene("Teflon") | Good |
| Polymonochlorotrifluoroethylene | Good |
| Polyisobutylene | Good |
| Styrenes | |
| Polystyrene | Good |
| Polydichlorostyrene | Good |
| Vinyls and vinylidenes | |
| Polyvinyl chloride | Good |
| Polyvinyl acetate | Poor |
| Polyvinyl chloride-acetate | Good |
| Polyvinylidene chloride | Good |
| Polyvinyl butyral | Good |
| Glyptal resins (Alkyd resins) | Poor, moderate |
| Silicone resins | Good |

[a]Some cases are on record in which phenol-formaldehydes have been listed as poor. This difference in opinion probably arises from testing samples containing susceptible fillers since the resin itself is considered as having rather good fungous resistance.

[b]White and Siu, in tests on cotton fabrics impregnated with urea-formaldehyde and melamine-formaldehyde resins, found that a high degree of fungous resistance was imparted to the cotton by the resins. It was not conclusively shown, however, whether the resistance was due to the resins as such or to the possible presence of free formaldehyde.

[c]Some tests have indicated nylon to be attacked in soil burial, but most evidence shows it to be immune.

[d]Klemme and Watkins reported that the susceptibility of polyethylene and polyisobutylene resins to fungous growth decreases as the average molecular weight (mw) increases. Ethylene materials of molecular weights above 10,000, and a butylene sample of 100,000 mw, were found to be fairly resistant. Polytrifluorochloroethylene ("Kel-F") shows a nutritive inertness comparable to the high-molecular-weight polyethylene.

## 15-6 DETERIORATION OF PLASTICS †

With the wide variety of plastics available today, it is possible to choose a plastic that is not affected by the particular environmental conditions to which it is exposed. The resistance of plastics to corrosion, light, heat, acids, alkalies, organic solvents, etc., can be found in various materials handbooks and manufacturers' brochures. It can be said that, in general, plastics have a good resistance to corrosion and chemical action.

### 15-6.1 MICROORGANISMS

Although some plastics are synthesized from and contain some natural materials, for the most part the plastics are synthesized by the chemical industry. These synthetic polymers have few constituents that occur in nature as part of living cells, and only a few microorganisms have enzyme systems capable of biodegrading plastics. The plasticizer, added to give desired qualities, is the most vulnerable component subject to attack by microorganisms. When the plasticizer is removed by microbial growth, the plastic becomes brittle. Staining and odor created by microbial growth also may be a problem. Generally, however, plastics are relatively resistant to attack by microorganisms and, in these cases, deterioration rarely proceeds beyond the surface—thin coatings could present a problem in these cases. Table 15-12 lists the relative resistance of several plastics to microbial attack.

### 15-6.2 CHEMICALS

Chemical deterioration of plastics results in loss of strength, erosion warpage, cracking, and loss of transparency. Most physical changes are caused by loss of plasticizer. The chemical resistance of various plastics is indicated in Tables 15-13 and 15-14.

### 15-6.3 TEMPERATURE

As the temperature drops, plastics tend to lose their flexibility and become brittle. The temperature at which this happens varies with each different plastic. Polyethylene, one of the more durable plastics, begins to stiffen slightly at -30°F and becomes brittle at -94°F. Teflon remains flexible and retains its strength down to -50°F.

At the higher temperatures, plastics become very flexible and begin to lose their strength.

†For a more thorough discussion of deterioration, refer to Engineering Design Handbooks: AMCP 706-116, *Environmental Series, Part Two, Natural Environmental Factors*; and AMCP 706-121, *Packaging and Pack Engineering*.

## TABLE 15-13. CHEMICAL RESISTANCE (TENSILE STRENGTH) OF REINFORCED PLASTICS AT ROOM TEMPERATURE

| | Glass Filler, wt% | Sulfuric Acid, 10% | | | | Ammonium Hydroxide | | | | Ethylene Glycol | | | | Methanol | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | unstressed | | stressed | | unstressed | | stressed | | unstressed | | stressed | | unstressed | | stressed | |
| | | Numerical Ranking[a] | Resistance[b] | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance |
| ABS[c] | 30 | 4 | A | 10 | F | 7 | F | 12 | X | 8 | E | 10 | A | 14 | X | 16 | X |
| SAN[d] | 30 | 6 | F | 9 | F | 11 | X | 7 | F | 3 | E | 14 | F | 18 | X | 18 | X |
| Polystyrene | 30 | 14 | X | 13 | X | 12 | X | 11 | X | 14 | A | 17 | F | 16 | X | 17 | X |
| Polycarbonate | 30 | 9 | F | 4 | A | 15 | X | 16 | X | 9 | E | 16 | F | 9 | F | 10 | F |
| | 0 | 3 | A | 6 | F | 17 | X | 17 | X | 15 | F | 11 | A | 7 | A | 7 | A |
| Polyethylene | 30 | 10 | F | 8 | F | 16 | X | 15 | X | 12 | E | 9 | A | 6 | A | 9 | F |
| Polysulfone | 30 | 7 | F | 11 | F | 10 | F | 9 | F | 7 | E | 7 | E | 8 | A | 6 | A |
| Polyacetal | 30 | 13 | F | 14 | X | 9 | F | 10 | X | 16 | F | 12 | A | 10 | F | 11 | F |
| | 0 | 18 | X | 15 | X | 1 | E | 1 | E | 4 | E | 2 | E | 4 | E | 4 | E |
| Polypropylene | 30 | 5 | A | 3 | A | 4 | A | 4 | A | 2 | E | 4 | E | 1 | E | 5 | A |
| Nylon 6 | 30 | 17 | X | 18 | X | 14 | X | 14 | X | 10 | E | 6 | E | 11 | F | 3 | E |
| Nylon 6/10 | 30 | 11 | F | 7 | F | 8 | F | 8 | F | 11 | E | 8 | E | 12 | X | 12 | X |
| Nylon 6/6 | 30 | 16 | X | 16 | X | 13 | X | 13 | X | 17 | F | 15 | F | 13 | X | 13 | X |
| | 0 | 15 | X | 17 | X | 18 | X | 18 | X | 18 | X | 18 | X | 15 | X | 14 | X |
| Thermoplastic Polyurethane | 30 | 8 | F | 5 | F | 6 | F | 6 | F | 17 | X | 15 | X | 17 | X | 15 | X |
| PVC | 15 | 1 | E | 1 | E | 3 | E | 3 | E | 3 | E | 1 | E | 3 | E | 1 | E |
| Thermoplastic Polyester | 30 | 12 | F | 12 | F | 5 | F | 5 | F | 5 | E | 8 | A | 5 | E | 8 | A |
| Modified PPO[e] | 30 | 2 | A | 2 | A | 2 | E | 2 | E | 5 | E | 5 | E | 2 | E | 1 | E |

| | Gasoline | | | | Motor Oil | | | | Brake Fluid | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | unstressed | | stressed | | unstressed | | stressed | | unstressed | | stressed | |
| | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance |
| ABS[c] | 16 | X | 15 | X | 10 | F | 13 | F | 17 | X | 16 | X |
| SAN[d] | 12 | X | 16 | X | 18 | X | 15 | F | 18 | X | 17 | X |
| Polystyrene | 17 | X | 16 | X | 14 | F | 18 | X | 9 | F | 17 | X |
| Polycarbonate | 9 | F | 8 | F | 15 | F | 17 | F | 14 | F | 12 | X |
| | 8 | F | 10 | X | 12 | F | 14 | F | 11 | F | 14 | X |
| Polyethylene | 11 | F | 9 | X | 4 | E | 6 | E | 6 | A | 6 | A |
| Polysulfone | 14 | X | 14 | X | 5 | E | 4 | E | 15 | X | 13 | X |
| Polyacetal | 2 | E | 2 | E | 1 | E | 1 | E | 1 | E | 3 | E |
| | 1 | E | 1 | E | 2 | E | 3 | E | 2 | E | 1 | E |
| Polypropylene | 15 | X | 3 | A | 7 | A | 7 | A | 5 | A | 2 | E |
| Nylon 6 | 7 | F | 6 | F | 9 | A | 8 | A | 7 | A | 5 | A |
| Nylon 6/10 | 6 | F | 7 | F | 11 | F | 12 | F | 8 | A | 8 | A |
| Nylon 6/6 | 5 | F | 11 | X | 16 | F | 11 | A | 13 | F | 7 | A |
| | 10 | F | 12 | X | 17 | F | 9 | A | 10 | F | 9 | A |
| Thermoplastic Polyurethane | 13 | X | 13 | X | 13 | F | 16 | F | 16 | X | 15 | X |
| PVC | 4 | F | 5 | F | 8 | A | 9 | A | 12 | F | 10 | F |
| Thermoplastic Polyester | 3 | A | 4 | A | 6 | E | 5 | E | 3 | E | 4 | A |
| Modified PPO[e] | 17 | X | 16 | X | 3 | E | 2 | E | 4 | E | 11 | F |

[a]Numerical ranking of the material chemical combination in group. (Number 1 is highest.)
[b]Resistance Code:
E = Excellent: 0-3% loss of tensile strength
A = Acceptable: 3-10% loss of tensile strength
F = Fair: 10-25% loss of tensile strength
X = Unacceptable: more than 25% loss of tensile strength

[c]ABS = acrylonitrile butadiene styrene
[d]SAN = styrene acrylonitrile
[e]PPO = polyphenylene oxide

## TABLE 15-14
## CHEMICAL RESISTANCE (TENSILE STRENGTH) OF PLASTICS AFTER EXPOSURE FOR 72 h AT 180°F (82°C)

| Basic Polymer | Hydrochloric Acid, 10% | | Ammonium Hydroxide[a], 10% | | Ethylene Glycol | | Methanol | | Gasoline | | Motor Oil | | Brake Fluid | | Carbon Tetrachloride | | Benzene | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Numerical Ranking[b] | Resistance[c] | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance | Numerical Ranking | Resistance |
| ABS[d] | 7 | F | 6 | X | 7 | F | 9 | X | 11 | X | 12 | F | 10 | X | 11 | X | 8 | X |
| Polystyrene | 8 | F | 9 | X | 9 | F | 13 | X | 12 | X | 9 | F | 10 | X | 11 | X | 8 | X |
| Polycarbonate | 3 | F | 12 | X | 4 | A | 8 | X | 5 | F | 3 | E | 10 | X | 6 | F | 8 | X |
| Nonreinforced Polycarbonate | 2 | A | 12 | X | 8 | F | 5 | F | 9 | X | 5 | A | 10 | X | 7 | X | 8 | X |
| Polyethylene | 6 | F | 7 | X | 6 | A | 3 | F | 7 | X | 6 | A | 3 | A | 8 | X | 5 | F |
| Polysulfone | 5 | F | 5 | F | 3 | E | 4 | F | 8 | X | 2 | E | 9 | X | 9 | X | 8 | X |
| Polyacetyl | 11 | X | 4 | F | 10 | F | 7 | F | 3 | F | 8 | F | 6 | F | 5 | F | 6 | X |
| Nonreinforced Polyacetyl | 11 | X | 1 | E | 2 | E | 1 | E | 1 | E | 1 | E | 2 | E | 1 | E | 1 | E |
| Polypropylene | 4 | F | 5 | F | 5 | A | 6 | F | 10 | X | 13 | F | 4 | A | 10 | X | 7 | X |
| Nylon 6/10 | 9 | X | 11 | X | 11 | X | 10 | X | 2 | A | 4 | A | 5 | A | 2 | E | 2 | A |
| Nylon 6/6 | 10 | X | 12 | X | 12 | X | 11 | X | 6 | F | 10 | F | 7 | F | 4 | A | 3 | F |
| Nonreinforced Nylon 6/6 | 11 | X | 11 | X | 13 | X | 12 | X | 4 | F | 11 | F | 8 | X | 2 | E | 4 | F |
| Modified PPO[e] | 1 | E | 1 | E | 1 | E | 2 | E | 12 | X | 7 | A | 1 | E | 11 | X | 8 | X |

[a]Test temperature 65°F (18°C)
[b]Numerical ranking of the material/chemical combination in group. (Number 1 is highest.)
[c]Resistance Code:
- E = Excellent: 0-3% loss of tensile strength
- A = Acceptable: 3-10% loss of tensile strength
- F = Fair: 10-25% loss of tensile strength
- X = Unacceptable: greater than 25% loss of tensile strength

[d]ABS = acrylonitrile butadiene styrene
[e]PPO = polyphenylene oxide

# INDEX

## A



## B



## C

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